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The Canadian Entomologist

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The Canadian Entomologist

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Development, Feeding Habits, and Predator-Prey Relations of Insect Predators of the Balsam Woolly Aphid, *Adelges piceae* (Ratz.) (Homoptera: Adelgidae), Recently Introduced into Canada[1]

By B. C. Smith[2]

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Smith and Coppel (in preparation) listed the releases and reviewed the bionomics in Europe of insect predators of the balsam woolly aphid, *Adelges piceae* (Ratz.), recently introduced into Canada. The most promising species released since 1951 are *Aphidecta obliterata* (L.) and *Pullus impexus* (Muls.) (Coleoptera: Coccinellidae), *Cremifania nigrocellulata* Cz. (Diptera: Chamaemyiidae), and *Laricobius erichsonii* Rosenh. (Coleoptera: Derodontidae). All these species, with the possible exception of *A. obliterata*, are established near Fredericton, New Brunswick. Investigations in co-operation with the Forest Biology Laboratory, Fredericton, were begun in 1951 on the behaviour and initial establishment of the introduced predators (Clark, Brown, and Smith, 1954). The present paper contains field and laboratory observations on the development, feeding habits, and predator-prey relations of the four promising species.

Materials and Methods

Adults of the predatory species were taken from the shipments from Europe, and larvae were reared from these adults and also collected in areas where adults were released in the field.

Development

Observations on development were made of predators released in the open and in cube-shaped cages erected around the trunks of trees infested with *A. piceae*. Details of releases for the cage studies are as follows: *Aphidecta obliterata* was investigated in 1955 with 10 gravid females released on May 16; *Cremifania nigrocellulata* in 1954 with 168 adults of undetermined sex released on June 4; and *Laricobius erichsonii* in 1951 with 18 mated pairs released on June 5, in 1953 with seven pairs released on May 17, and in 1955 with 14 pairs released from May 19 to 26. In 1954 a similar cage study was conducted with 100 late-second- and early-third-instar larvae of *C. nigrocellulata* released on June 23, and 100 late-third- and early-fourth-instar larvae of each of *L. erichsonii* and *Pullus impexus* released on June 14 and June 2 respectively.

Feeding Habits

Whenever possible, observations on feeding were made in the field, but detailed observations were only possible in the laboratory because of the small size of predators and prey. The stages of the predators studied were the larvae in all instars of *C. nigrocellulata* and the larvae in all instars and adults of *A. obliterata*, *L. erichsonii*, and *P. impexus*. Various stages of the prey were exposed to each of these stages of the predators in the laboratory at a temperature of approximately 18°C. and a relative humidity of approximately 80 per cent. The nymphs and adults of the aphids *Mindarus abietinus* Koch., *Macrosiphum ambrosiae* Thomas, and *Periphyllus populicolus* Thomas, and the eggs, motile first-

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instar larvae or crawlers, sessile first-instar larvae, second- and third-instar larvae, and adults of *A. piceae* were exposed to *A. obliterata*. All stages of the aphid *Myzus persicae* (Sulz.), the mealybug *Pseudococcus* sp., and *A. piceae* were exposed to *C. nigrocellulata*, *L. erichsonii*, and *P. impexus*. Except for the first-instar larvae of *P. impexus*, which were not available in sufficient numbers, at least 15 tests of predation were conducted with at least 10 individuals of the various stages of the predators and *A. piceae* on pieces of bark cut from prey-infested trees. In these tests each bark unit was examined microscopically at intervals of 24 hours and the number of prey destroyed was estimated, and if no prey remained the bark unit was replaced. This procedure was also followed in the rearing of at least five larvae of each predatory species and determination of the duration of each instar under laboratory conditions.

Predator-Prey Relations

Changes in numbers of *A. piceae* exposed to the various predators in the cube-shaped cages were determined; and the changes in all cages except those with *L. erichsonii* in 1951 and 1953 were compared with changes in numbers of *A. piceae* in the absence of predators in sleeve-cages each placed above a cube-shaped cage. Additional studies on change in numbers of *A. piceae* in the absence of predators were made in 1954 in an infestation having exactly one adult per square inch in the first generation – all other stages were removed – and confined by a sleeve-type cage, and in 1955 on two trees having approximately 12 and 18 adults and second- and third-instar larvae per square inch in the first generation, and each with a cube-shaped and a sleeve-cage. The cages (Figs. 1-4) each enclosed bark areas of approximately 800 square inches. The sides of the cube-shaped cage were four feet long. The top and sides were covered with fine-mesh plastic screen and two opposing sides were detachable to permit inspection of the enclosed bark. The bottom consisted of a large box each half of which formed a separate box to fit the shape of the tree. The cage met the trunk at top and bottom with collars of galvanized tin to which strips of muslin were attached to ensure close fit. The sleeve-cage was attached at its top and bottom to fabric collars that encircled the trunk, and was removed for inspection of the insects enclosed. The surface of bark enclosed by both types of cage was divided into one-square-inch sections by lengths of thread strung vertically and horizontally. At the top and bottom of each cage, small areas from which the stages of the first generation of *A. piceae* were removed were left undivided.

The predatory species present, including *Neoleucopis obscura* (Hal.) (Diptera: Chamaemyiidae), were removed from the caged bark surfaces before predators were released. After the releases, when predatory larvae were present they were counted daily. The abundance of predatory larvae in each cage study was expressed as larva-days. Predation by adults was negligible because of the small numbers present. Censuses of second- and third-instar larvae and adults of the first generation of *A. piceae* were made before the predatory larvae were present, and censuses of the second generation were made when mainly adults were present except in 1953 in the cage with *L. erichsonii*. Here, the ratio of adults to larvae was 0.8. When the censuses of the first generation of *A. piceae* were made, adults were most abundant in all cage studies except that with *A. obliterata* in 1955. The average number of *A. piceae* per square inch in the first and second generations and its standard error were calculated for each cage study. Percentage change in the numbers of *A. piceae* in the cages were calculated on a basis of the censuses.

Figs. 1-4. Two cages used in studies of development of predatory species and predator-prey relations. 1. Areas of bark enclosed by cube-shaped cage and sleeve-cage. 2. Sectioned area of bark enclosed by cube-shaped cage. 3. Sectioned area of bark enclosed by sleeve-cage, and fabric collars to which cage was attached. 4. Part of square-inch section of bark with sessile first-instar larvae (one encircled) and wax masses of adults of *A. piceae*.

Development

The oviposition of *Aphidecta obliterata* began one day after release of the gravid females and continued for 35 days. The oviposition period is probably longer than this as the females were at least three weeks old when released. The maximum number of eggs, approximately 17 eggs per female per day, was laid four days after release. Each female laid an average of 52. The eggs were laid singly and in clusters on the surface of the bark outside the wax masses of *A. piceae*, and also at the extremities of short twigs. Though the average number of eggs in each cluster was four, some clusters were found with as many as 11 eggs. The distribution of eggs showed no direct relationship to the distribution of larvae and adults of *A. piceae*. The eggs were cemented to the bark with the long axis perpendicular to its surface. Under field conditions, where the temperature ranged from 4° to 26°C., the incubation period averaged 8.5 days and ranged from four to 13 days. Immediately after oviposition the eggs were pale yellow in colour. They subsequently turned orange and finally gray. The gray stage lasted for one day before hatching. Mortality of eggs was 68 per cent and was caused chiefly by predation by the first-instar larvae. Larvae were present for approximately 40 days, there being considerable overlapping of the four instars. During ecdysis the larvae attached itself to the bark by its posterior end. Exuviae were found on the bark outside the wax masses of *A. piceae*. The estimated mortality of the larvae, some of which was caused by cannibalism, was 19 per cent. Approximately one day before pupation, the last-instar larva attached itself to the bark by an exudation from the anus. The pupal period lasted eight days. The adults were inactive for approximately two weeks after emergence and were found in crevices at the bottom of the cage. Confined adults mated within three weeks of emergence, coitus lasting approximately three hours. Though in confinement the mated females fed voraciously on the second generation of *A. piceae*, no eggs were laid. Each released female produced an average of 6.2 adults.

Only the first generation of *Cremifania nigrocellulata* was observed, so that less detail was obtained than for *A. obliterata*. Some of the females lived in the cage for 16 days after release. Though mating was not observed, eggs were found seven days after release. First-instar larvae occurred two weeks after release of the adults. Larvae were present for approximately 12 days and there was little overlapping of the three instars. In the laboratory, puparia were formed on the bark units near the feeding sites of the last-instar larvae. In the field the majority of the puparia were found at the base of the trunk on which the larvae fed. Adults of the second generation emerged approximately 65 days after the initial release.

In *Laricobius erichsonii* coitus lasted approximately 30 minutes and more than one mating occasionally occurred. Two males were often found attached to one female. The males lived approximately 12 days after mating, the females approximately 28. Though not found in the field, eggs were found in the laboratory on bark cut from caged areas of trees infested by *A. piceae* and exposed to the adults. The eggs were found in the wax near the eggs of the prey. The egg was pale yellow in colour and approximately the same size as that of *A. piceae*. First-instar larvae occurred approximately three weeks after release of the mated pairs, and the total duration of the four instars on the first generation of *A. piceae* was three weeks. The average number of last-instar larvae developing from one female in three cage studies was 10.6. In a fourth cage, the number of *A. piceae* was insufficient for the larvae to mature. On completion of feeding, the fourth-instar larvae left the trunks and entered the

soil, where they pupated. The majority of the pupae were found in the first two inches of mineral soil and within 18 inches of the base of the trunk on which the larvae fed. The approximate periods spent in the soil were as follows: inactive last-instar larva, five days; pupa, 11; and inactive adult, three to four. Before hibernating, the adults returned to infestations of *A. piceae* to feed on the second generation.

Eggs of *Pullus impexus* were found in the late summer, approximately six weeks after release of adults in the open. The eggs were orange-coloured and occurred singly in crevices or under lichen on the bark. Larvae occurred early in the spring on the first generation of *A. piceae*. The eggs hatched in the spring and feeding larvae were present for approximately three weeks. The fourth-instar larva had a duration of approximately 15 days, of which seven were passed in an inactive state preceding pupation on the bark. The pupal period lasted 10 days, and adults emerged during the first two weeks of July.

Feeding Habits

Last-instar larvae of *Aphidecta obliterata* were found in field infestations of *Mindarus abietinus*, and in the laboratory *A. obliterata* attacked nymphs and adults of *Macrosiphum ambrosiae* and *Periphyllus populicolus* in the laboratory though they were not found in infestations of these aphids in the field. The larvae of *Cremifania nigrocellulata*, *Laricobius erichsonii*, and *Pullus impexus* were not observed to attack any stage of *Myzus persicae* or *Pseudococcus* sp. The presence of predatory larvae in infestations of *A. piceae* was indicated by distortion of the wax masses covering the prey. The distortion was more pronounced in infestations exposed to *C. nigrocellulata*, *L. erichsonii*, and *P. impexus* than in those exposed to *A. obliterata*. The reason for this difference is that the early-instar larvae of the first three species fed with their abdomens wholly or partly within the wax masses, whereas the larvae of *A. obliterata* fed from outside the masses.

Feeding of Adults on A. piceae

A. obliterata adults attacked the crawler but not the sessile first-instar larva. One minute was required for an adult to consume an egg of the prey; the whole egg, including the associated strand of wax, was ingested. Second- and third-instar larvae and adults were consumed in their entirety, including integuments and associated wax. A larva was consumed in two minutes and an adult in three.

L. erichsonii adults did not attack the first-instar larva. The egg was punctured and its contents ingested. Occasionally, the egg shell was eaten. An adult took from four to six minutes to consume an egg. Often, an egg was punctured but not completely consumed. The consumption of a second- or third-instar larva took approximately four minutes and of an adult approximately five. Integuments and wax were usually not ingested.

P. impexus adults attacked the crawler and the sessile first-instar larva when the other stages were not available to them. The consumption of one first-instar larva took one minute. An egg was ingested whole in three minutes. Second- and third-instar larvae were preferred to eggs. The consumption of a larva took approximately three minutes and of an adult approximately five. Integuments were usually not ingested, but wax was often eaten.

The average number of *A. piceae* consumed in 24 hours by predatory adults was:—

	Number of Tests	*Eggs*	*Crawlers*	*Second- and Third-instar Larvae*	*Adults*
A. obliterata	7	12.2		0.6	1.6
L. erichsonii	28	5.2		0.3	0.7
P. impexus	46	13.9	0.2	1.3	1.7

Feeding of Larvae on A. piceae

With the exception of *A. obliterata* the larvae of the predators neither attacked the first-instar larva of *A. piceae* nor consumed wax, integuments, and egg shells. The fourth-instar larva of *A. obliterata* attacked the crawler occasionally. The first-instar larva of *C. nigrocellulata* fed chiefly on eggs and honeydew.

The durations of the feeding periods and the average numbers of eggs, larvae, and adults consumed per larva in the various instars were:—

	Number Observed	Duration, Days	Eggs	Second- and Third-instar Larvae	Adults
A. obliterata					
First	5	3	41		10
Second	5	3	77		22
Third	5	3	222		42
Fourth	5	4	347		82
C. nigrocellulata					
First	10	4	11		1
Second	9	5	21		2
Third	9	9	59		8
L. erichsonii					
First	25	3	13		
Second	20	4	126	2	15
Third	20	5	435	1	45
Fourth	20	5	1060	16	210
P. impexus					
First*	2	5			
Second	20	4	45	14	10
Third	17	4	134	10	15
Fourth	17	8	426	53	64

*There were not sufficient observations to estimate the number consumed by this stage.

Predator-Prey Relations

Table I shows that in the cage studies the predators caused appreciable decreases in numbers of *A. piceae* by the second generation on trees A, B, and D. The failure on tree C may be attributed to the fact that only late-instar

TABLE I

Percentage changes in numbers of *A. piceae* based on first and second generation censuses in cages on trees after exposure to larvae of various predators for various periods in the first generation (figures for controls in parentheses)

Tree	Predator			Number of *A. piceae*		
	Species	Time of occurrence	Larva —days	Per square inch, first generation	Per square inch, second generation	Percentage changes in second generation
A	*A. obliterata*	May 26–July 4	1,487	38.68 ± 1.41 (19.92 ± 0.53)	29.67 ± 0.70 (31.48 ± 0.62)	−25 (+56)
B	*C. nigrocellulata*	June 17–June 28	1,232	38.08 ± 1.05 (44.19 ± 1.07)	11.57 ± 0.29 (44.19 ± 1.29)	−70 (−0.05)
C	*C. nigrocellulata*	June 22–June 26	210			
C	*L. erichsonii*	June 14–June 20	.317	26.74 ± 0.68 (38.33 ± 0.97)	41.77 ± 0.63 (46.77 ± 0.93)	+51 (+21)
C	*P. impexus*	June 2–June 12	673			
D	*L. erichsonii*	June 17–July 7	836	16.62 ± 0.35 (26.98 ± 0.46)	19.55 ± 0.33 (61.05 ± 0.88)	+18 (+124)
E	*L. erichsonii*	June 12–July 4	652	3.10 ± 0.01	1.50 ± 0.03	−47
F	*L. erichsonii*	June 25–July 20	896	36.90 ± 1.01	63.50 ± 1.06	+70

larvae of the predators were present and consequently predation was less sustained. Predators probably decreased the numbers on tree E but were not effective on F because they occurred after the crawler and the sessile first-instar larva became abundant.

The factors that exercised the greatest influence on change in numbers of *A. piceae* in the absence of predators were the suitability of the tree as a feeding site, and competition for food and space by the stages of *A. piceae*. Competition for space was most severe at high density, and infestations with high initial densities had smaller increases than those with low initial densities as indicated in the controls on trees A to D. The greatest increase in numbers of *A. piceae* by the second generation was 223 per cent, and this occurred in an infestation that had an initial density of one per square inch. When changes in numbers of *A. piceae* in the infestations with predators are compared with changes in numbers in the control infestations, allowance must be made for differences in the initial densities.

When a tree has become heavily infested it may show resistance to injury by laying down a secondary periderm below the tissue that has been killed by the feeding (Balch, 1952). The greatest decreases in numbers of *A. piceae* by the second generation occurred in predator-free infestations on trees with extensive development of secondary periderm. The infestations on these trees were probably declining because of inadequate food, and the relationship between initial density and change in numbers of *A. piceae* was as follows:—

Initial number of *A. piceae* per square inch	10.88±0.41	12.80±0.37	16.81±0.34	19.74±0.18
Percentage change	−80	−47	−38	+24

The smaller decreases occurred in infestations with the higher initial densities.

Mortality of *A. piceae*, though not measured directly, was high in all infestations studied. In some, the bark of a number of the divided areas was almost completely obscured by sessile first-instar larvae, the progeny of first-generation adults. Large numbers of these larvae did not develop further. Balch (*loc. cit.*) reported that females of the first generation of *A. piceae* laid an average of 100 eggs and those of the second generation an average of 50, giving an annual potential reproduction of X5000 for an average population. On a basis of these figures, the estimated mortality of the first generation was approximately 97 per cent in the control study with an initial density of one per square inch and an increase of 223 per cent in the second generation.

Discussion

The observations on the life-histories of the predatory species generally agree with those made in Europe by Delucchi (1953) on *Aphidecta obliterata*, by Delucchi and Pschorn-Walcher (1954) on *Cremifania nigrocellulata*, by Franz (1953) on *Laricobius erichsonii*, and by Delucchi (1954) on *Pullus impexus*. However, the present observations do not take into consideration seasonal variations, and, particularly for *A. obliterata* and *C. nigrocellulata*, are not complete.

C. nigrocellulata, *L. erichsonii*, and *P. impexus* are more specialized in feeding habits than *A. obliterata* and their prey are probably confined to the genus *Adelges*. The control value of the predators of *A. piceae* is limited, as the first-instar larva is rarely attacked, the crawler only by adults of *A. obliterata* and *P. impexus* and by last-instar larvae of *A. obliterata*, and the sessile form only by adults of *P. impexus*. These observations on feeding habits agree

with those of investigators in Europe as summarized by Pschorn-Walcher and Zwolfer (1956) except that in Europe the larvae of the four predators attacked the crawler. The rates of destruction of *A. piceae* by adults of *A. obliterata*, *L. erichsonii*, and *P. impexus* are high but the adults may not be of importance in control as large numbers were not found in the field. From the point of view of the total number of *A. piceae* destroyed, the last-instar larvae of the predators are the most important, but the value of these stages is limited because they do not attack all the stages.

The effectiveness of the predatory species depends in part on the time of occurrence of their larvae in relation to that of first-instar larvae of *A. piceae*. Next to the egg the first-instar larva is the most abundant stage, and the sessile form is present the year around. At high density, competition of *A. piceae* for food and space is severe, and relatively few progeny of the first generation survive to the adult stage. The number in excess of what a tree can support is sufficient to maintain a considerable number of predators. The predatory larvae are most effective when they are present early enough to destroy more than this excess.

Summary

Investigations on insect predators at Fredericton, New Brunswick, indicated that the development of *Aphidecta obliterata*, *Cremifania nigrocellulata*, *Laricobius erichsonii*, and *Pullus impexus* on *A. piceae* is generally similar to that in Europe. *A. obliterata* attacked *Mindarus abietinus* on the twigs of balsam fir, and may attack the stages of *A. piceae* that cause gout. Larvae of *C. nigrocellulata*, *L. erichsonii*, and *P. impexus* did not attack *Myzus persicae* or *Pseudococcus* sp., and the prey of these predators are probably confined to the genus *Adelges*. The value of the predators in control of *A. piceae* is limited because few of their stages attacked the crawler or the sessile first-instar larva. In cage studies in the field the larvae of the predators reduced the numbers of *A. piceae* appreciably when present before the first-instar larvae became abundant.

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Studies of Parasite Oviposition Behaviour. II. *Leptomastix dactylopii* Howard (Hymenoptera, Encyrtidae)

By D. C. Lloyd
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Introduction

Entomophagous insects as a group show all degrees of host preferences from the polyphagous species which develop on variable numbers of hosts to the strictly monophagous forms which are limited to development on a single host species. Polyphagy is generally regarded as the more primitive condition while the fact that even among species so characterized there frequently exist strong preferences in the form of host determined races is taken as an indication of one method by which the more specialized habit was attained. The general problem of the dynamics of host selection in the entomophagous Hymenoptera and Diptera has attracted the attention of numerous investigators (eg. Thompson & Parker 1927, Salt 1935, Ullyett 1936) and many have stressed that for any given parasite the range of hosts attacked and developed on is the end result of various processes. These processes have been conveniently described by Salt (1938) as host finding, selection, and suitability, the first phase being more usually referred to as habitat selection (Flanders 1937, Thorpe 1945). This interpretation has received wide acceptance among biological control and allied workers.

It is proposed here to consider some aspects of this problem of the means by which host preference is implemented in the encyrtid *Leptomastix dactylopii*. Since the behaviour patterns involved in this type of biological interaction are many and not equally suitable for laboratory investigation, only those relating to active selection once the adult parasite is in the immediate vicinity of the hosts have been examined experimentally.

L. dactylopii is a solitary internal parasite of third nymph and adult mealybugs and an interesting example of a species which is, for all practical purposes, a monophagous parasite under natural conditions, yet its polyphagous potentialities are easily demonstrated in the laboratory. Thus Muesebeck et al. (1951) list as hosts the mealybugs *Planococcus citri* (Risso), *Pseudococcus maritimus* (Ehrh), *P. comstocki* (Kuwana), *P. gahani* Green, *P. adonidum* (L.), *Phenacoccus gossypii* Towns. & Ckll., and *Ph. solani* Ferris, these data being based on laboratory rearing by Bess (1939) and Clancy (1944). The field host is *Pl. citri* and although Fullaway (1946) states that the encyrtid was bred by him from mixed colonies of *Planococcus kraunhiae* (Kuwana) and *Ph. gossypii* infesting egg plant and soybean at Honolulu, Hawaii, the record must be questioned in view of the assertion of Ferris (in Zimmerman 1948) that all Hawaiian mealybug material hitherto described as *Pl. kraunhiae* has been shown to be *Pl. citri*. There is a later record by Swezey (1949) of *Leptomastix* from the usual host *Pl. citri* on poinsettia in Honolulu. Howard (1885) and Compere (1939) described specimens reared from *Pl. citri* on numerous plants in the Southeastern United States, the West Indies, and S. America, while Kirkpatrick (1953) stated that in Trinidad *L. dactylopii* "appears to be restricted to *Pl. citri* and will not attack the other mealybug species found on cacao." These other species include *Dysmicoccus brevipes* (Ckll.), *P. adonidum* (L.) *P. comstocki* (Kuwana) and *Ferrisiana virgata* (Ckll.). Kerrich (1953) records a single female *L. dactylopii* ex *Pseudococcus inamabilis* Hambleton, a mealybug reported as causing damage to the conifer *Cupressus glauca* in Sao Paulo, Brazil (Hambleton 1935). There is no indication as to whether the parasite is consistently found in infestations of

this host. In general, the foregoing observations of the restriction to *Pl. citri* as a host are in accord with Californian field experiences. Annual releases of many millions of *L. dactylopii* have been made in *Pl. citri* infestations by citrus growers cooperatives of S. California since introduction of the parasite from Brazil in 1934 yet it has not been recorded there in collections of other common citrus mealybugs (Clausen 1956, Bartlett & Lloyd 1958).

An interpretation of these data in terms of the conventionally recognized processes of host preference dynamics largely centres on the behaviour of the female parasite when confronted with different host species. The importance of this behaviour pattern is emphasized by the following considerations. At an average temperature of 80° F, which may be taken as representative of conditions in its normal tropical environment, the female *L. dactylopii* commences oviposition within a few hours of emergence. Parasitized hosts ("mummies") almost invariably remain embedded in the feeding mealybug colony at any particular site so that the recently emerged adult is already in the habitat of its host *Pl. citri* and there is no good reason to assume the female immediately leaves it if acceptable host stages are present. This habitat, however, is of uncertain definition relative to those of other mealybug species often present on the same plant and even occurring on the same plant organ (eg. fruit) as in the cited examples of cacao in Trinidad and citrus in California. Thus the question naturally arises as to how far this restriction to monophagy is an expression of an oviposition response adapted to specific releasing stimuli, since to claim that the observed field monophagy results from habitat selection is untenable.

The original demonstration of oviposition in hosts other than *Pl. citri* made by Bess (op. cit.) was incidental to his work on the resistance of mealybugs to parasitization by encyrtids, but his observations clearly showed that in the laboratory "wastage" does occur by egg laying in hosts unsuitable for progeny development. A more detailed study of the oviposition behaviour of this parasite is here reported on as a contribution to the wider field of host selection.

Oviposition in pure and mixed cultures of mealybugs

Experimental technique has consisted in simply exposing sets of single females to small numbers of hosts placed under one half of a petri dish of 60 mm diameter and 15 mm height. No control of spatial distribution of the hosts was attempted. Material was standardized by selecting mealybugs and adult parasites of 2 mm length, the hosts thus being in the adult stages. Female parasites of known age were obtained by early morning collection of all males and females emerging from masses of *Pl. citri* mummies within a brief period (1-2 hours usually) and then confining them in a one gallon jar with food until required for the experiments. Exposures were made in normal daylight at a constant temperature of 80° F $\pm$ 2° F and a relative humidity oscillating between 40 and 60%.

To examine possible differential oviposition action towards various mealybugs the species *Pl. citri*, *P. adonidum*, *P. maritimus* and *Ph. solani* were considered suitable, the first two being common in the parasite's tropical environment and the first three common in the citrus environment of California. *Ph. solani* occurs on solanaceous plants in western N. America and was chosen for contrast purposes as a mealybug type probably never encountered in the field by *Leptomastix*. All four species have the advantage of being easily maintained as laboratory cultures on sprouting potatoes.

Mixtures of 5 specimens of *Pl. citri* with 5 *P. adonidum*, 5 *Pl. citri* with 5 *P. maritimus*, and 5 *Pl. citri* with 5 *Ph. solani* were exposed for 2 hours to indivi-

TALBE I

Oviposition in mixed cultures of mealybugs available for two hour periods

Experiment Number	Hosts	Total Eggs Deposited	Mean Differences*
1	*Pl. citri*	25	
	P. adonidum	28	0.3± 0.61
2	*Pl. citri*	42	
	P. maritimus	12	3.0±0.69
3	*Pl. citri*	40	
	Ph. solani	10	3.0±0.78
4	*Pl. citri*	78	

* Per female oviposition ± standard error.

dual 48 hour old females which had been given no previous access to hosts. Ten replications were done for each mixture and as a control 10 females from the same stock were each given 10 *Pl. citri* in similar containers. Dissection gave the total ovipositions shown in Table 1. The 78 eggs found in dissecting the 100 *Pl. citri* in experiment 4 were distributed in 69 hosts, indicating a fair ability by this encyrtid to avoid oviposition in hosts already parasitized. There was a good rejection of *P. maritimus* and *Ph. solani* in mixed colonies but there was active oviposition in *P. adonidum.* Mixed colonies are not infrequent in mealybug field populations but it is often argued that in experimental work contact of the preferred host (*Pl. citri*) with other host species in small containers may contaminate the latter and thus affect the parasite's behaviour. An indication of the significance of this factor was obtained by exposing in the usual way 48 hour old females to 5 specimens of *Pl. citri* for one hour and then transferring the females to other containers with 5 *P. adonidum* etc. for a second hour. The oviposition behaviour for three sets of ten females is given in Table 2.

As expected most of the eggs were laid in the first hour of exposure to *Pl. citri* hosts, but the subsequent oviposition in the other hosts did not differ markedly from that obtained in the mixed cultures except in the case of *P. adonidum.* Heavy egg laying in the latter mealybug in mixed colonies may be in part an effect of nearby *Pl. citri.* The differences in oviposition behaviour in experiments 2, 3, 5, 6, and 7 are statistically significant ($P < 1\%$). The

TABLE II

Oviposition in pure cultures of mealybugs available for one hour periods

Experiment Number	Hosts		Total Eggs Deposited	Mean Differences
5	*Pl. citri*	1st hour	48	
	P. adonidum	2nd hour	15	3.3±0.66
6	*Pl. citri*	1st hour	47	
	P. maritimus	2nd hour	17	3.0±0.49
7	*Pl. citri*	1st hour	55	
	Ph. solani	2nd hour	3	5.2±0.46

TABLE III

Oviposition in pure cultures of mealybugs available for one hour periods

Experiment Number	Hosts		Total Eggs Deposited	Mean Differences
8	*P. adonidum*	1st hour	33	
	Pl. citri	2nd hour	34	0.1±1.01
9	*P. maritimus*	1st hour	12	
	Pl. citri	2nd hour	34	2.2±0.77
10	*Ph. solani*	1st hour	3	
	Pl. citri	2nd hour	47	4.4±0 62
11	*Pl. citri*	1st hour	40	
	Pl. citri	2nd hour	22	1.8±0.44

suggestion that the three non-field hosts per se are accepted in varying degrees as media for egg diposition was confirmed by reversing the experimental procedure and exposing sets of 48 hour old females to these hosts in groups of 5 specimens for the first hour and finally to *Pl. citri* for the second hour. The parasites here had been given no previous contact with the usual host although on emergence from the mummies some examination of the hardened, inflated host derms could have taken place. Oviposition by the 40 females in 400 mealybugs is given in Table 3. The control in the form of *Pl. citri* for both first and second hours was included as a measure of the extent of egg retention by *Leptomatix* in the presence of other mealybugs. The ready acceptance of *P. adonidum* under these conditions was somewhat surprising, but there were significant differences ($P < 2\%$) in behaviour in the first and second hours of the *maritimus/citri* and *solani/citri* experiments. Observation of the containers during these exposures indicated that the reduced egg laying in *P. maritimus* and *Ph. solani* was the result of inadequate stimulation. The females were quickly attracted to these hosts, which were then palpated, but the action frequently finished at this stage without any attempt at ovipositor release.

The foregoing experiments satisfactorily establish that the oviposition releasing stimuli in the mealybug hosts are not restricted to *Pl. citri*. This action of egg laying in various species of mealybugs is not a behaviour pattern exhibited solely in captivity in the laboratory. In observation in California citrus groves during the annual large scale releases of this parasite females have been found to lay in the *P. maritimus* colonies which are frequently common on the trees more heavily infested with *Pl. citri*. The extent of this oviposition in *P. maritimus* in the field has not been investigated but it is certain that some occurs, and the same may be inferred for *P. adonidum*. Collection of reliable quantitative data for this type of event is almost impossible since Bess (op. cit.) showed that *P. adonidum*, *P. maritimus*, *Ph. solani* etc. possess varying capacities of inhibiting development of *Leptomastix* eggs and larvae. These parasite stages are partially or completely destroyed within the mealybugs by immunity reactions and thus foreign bodies noted in dissections of field samples cannot be identified with any measure of confidence.

An indication of the relative suitability of the four mealybug species for development of *Leptomastix* progeny was obtained by exposing sets of ten

TABLE IV

Relative progeny production by *L. dactylopii* in cultures of four mealybug species

Host species	Numbers *Leptomastix* progeny	Mean progeny per 10 females
Pl. citri	363, 346, 379, 616, 256	392±60.1
P. maritimus	2, 2, 0, 1, 0	1± 0 45
P. adonidum	4, 7, 3, 0, 1	3± 1 2
Ph. solani	20, 27, 181, 39, 38	61±30.3

females to heavily infested potatoes in pint sized freezer jars for a week, removing these adult parasites after that interval, and subsequently collecting all emergents. Five replications were done for each host species, and the results are shown in Table 4. It is evident that *P. adonidum* and *P. maritimus* are completely unsuitable for progeny development in spite of the demonstrated attraction they exert as oviposition media. On the other hand *Ph. solani,* a mealybug which induces a relatively poor oviposition response in *L. dactylopii,* proves to be a host on which the encyrtid can maintain a fair population, and thus must be classified as a suitable one.

The conclusion from all the foregoing experiments is that the observed field monophagy of this parasite is not the result of a highly specialized oviposition response to one host, rather there appears to be an intrinsic tendency to "wastage" of eggs by their ready deposition in mealybugs unsuitable for progeny development.

Some effects of various environments on oogenesis in Leptomastix

It is obvious that an interpretation of this flexible oviposition response will be adequate only in so far as it rests on some knowledge of the basic processes and physiology of egg production in the adult *Leptomastix* and the modification of these environmental conditions, more particularly different host environments. As a first step an effort was made to record the cycles of egg maturation and resorption. This was necessary because in this parasite storage of ripe eggs occurs only at the bases of the six ovarioles and was known to be of limited duration. The phenomenon of egg resorption in some families of parasitic Hymenoptera has been established by Flanders (1942, 1950), Grosch (1950) and Edwards (1954-a): it need only be remarked here that in *Leptomastix* the process is especially well defined because the banded egg typical of the group of encyrtids including *L. dactylopii* leaves at the base of the ovarioles after resorption an unmistakable indissoluble remnant in the form of the band or so called aeroscopic plate (Maple 1947). For this study of egg maturation nine sets of 50 *Leptomastix* females, all collected within a 2 hour emergence period from *Pl. citri* mummies and of a selected uniform 2.0 mm length, were mated and then separated from the males and placed in nine one gallon jars. Each jar was streaked daily with honey as food, and a population of mealybug considered ample to meet oviposition requirements was maintained by addition of well infested sprouting potatoes every second day. Temperature, humidity and light conditions were those given for preceding experiments.

The various treatments in the jars were as follows, the containers in series C to I inclusive being changed on completion of the required exposure to *Pl. citri* populations.

Series A: *No hosts.*
B: *Pl. citri* for 15 days.
C: *Pl. citri* 1st 3 days of life, *no hosts* 4th to 15th days
D: *Pl. citri* 1st 3 days of life, *P. maritimus* 4th to 15th days.
E: *Pl. citri* 1st 3 days of life, *P. adonidum* 4th to 15th days.
F: *Pl. citri* 1st 6 days of life, *no hosts* 7th to 15th days.
G: *Pl. citri* 1st 6 days of life, *P. maritimus* 7th to 15th days.
H: *Pl. citri* 1st 6 days of life, *P. adonidum* 7th to 15th days.
I: *Pl. citri* 1st 9 days of life, *no hosts* 10th to 15th days.

On the 6th, 9th, 12th and 15th days of life of the *Leptomastix*, samples of 10 females were removed from each environment, the ovaries dissected out under a binocular microscope, and counts made of the mature and regressed eggs present. The numbers of these regressed eggs were then expressed as percentages of the sum of mature and regressed eggs in the ovaries, and the figures of Table 5 obtained. Each figure thus represents the average ovary condition at various life dates of 10 *Leptomastix* females so that dissection of 320 females involving counts of 10,454 mature and regressed eggs was done.

These experiments definitely show that under the given conditions resorption of mature eggs is associated with the absence of hosts (Series A, C, F and I), that it rarely occurs in the presence of adequate populations of the normal field host *Pl. citri* (Series B), and finally that it only takes place on a very minor scale in the sustained presence of "unsuitable" hosts (*P. maritimus* Series D and G; *P. adonidum* Series E and H). Egg resorption would be the extreme manifestation of a parasite's capacity for restraint or egg retention, and apparently this faculty is developed to a very poor degree in *L. dactylopii* having access to mealybugs. However, it is known that although the parasite does tend to avoid laying in parasitized hosts superparasitism is not uncommon, while there is also evidence that in comparable brief exposures to unsuitable hosts such as *P. adonidum* or *P. maritimus* appreciable oviposition occurs. Probably egg laying takes place on a proportionately increased scale when exposures to these hosts extend to days. These behaviour patterns are understandable when it is appreciated that the act of continually depositing eggs in hosts unsuitable for progeny development also maintains the ovary in a state of constant readiness for oviposition in suitable hosts. If the overriding priority in the economy of an adult hymenopterous parasite such as *L. dactylopii* is the maintenance of the gonads in such state that the cycles of oogenesis are uninterrupted or at maximum possible efficiency, then the data summarized in Table 5 throw doubt on the validity of classifying hosts as suitable and unsuitable in this particular case. Eggs resorbed may not be irretrievably lost as are those laid in unsuitable hosts but the behaviour in both instances is adaptive in the sense that it promotes species survival.

These considerations suggested the need for further investigation of the ovary condition with *Leptomastix* placed for definite periods first in micro-environments of unsuitable hosts, and subsequently in micro-environments of *Pl. citri*. Groups of freshly emerged females were accordingly secured and set up in the manner outlined for the preceding experiment. The hosts available in these universes were as follows:

Series J: *No hosts* 1st 15 days of life, *Pl. citri* 16th to 25th days.
K: *Pl. citri* 1st 25 days of life.
L: *P. maritimus* 1st 15 days of life, *Pl. citri* 16th to 25 days.
M: *P. adonidum* 1st 15 days of life, *Pl. citri* 16th to 25th days.

TABLE V

Effect of host environments on egg regression in ovaries of *Leptomastix* at various ages

Type of environment	Percentage of eggs regressed at age:			
	6 days	9 days	12 days	15 days
Series A	23.5	44.6	64.2	66.5
B	0	3.3	0	0
C	3.4	25.2	45.6	–
D	0	4.8	0	–
E	0	0	11.7	–
F	0	2.6	24.8	52.1
G	0	4.1	1.6	0.4
H	0	1.3	3.0	4.9
I	0	0	12.4	30.4

Samples of 10 females in each series were dissected on the 15th and 25th days of life. The regressed eggs in the ovaries were again expressed as percentages of the total mature and regressed eggs present. The resulting figures are given in Table 6. As anticipated there was no significant change in the occurrence of egg resorption between the 16th and 25th days when the normal field host was available to the ovipositing females.

It may be claimed that the experiments summarized in Tables 5 and 6 establish that oviposition in unsuitable hosts can be interpreted as adaptive behaviour only to the extent that egg resorption is a true indicator of the undisturbed functioning of the female gonads, with egg production at peak levels and comparable in all instances. This aspect is being further investigated but it must be pointed out here that proof of reduced ovary productivity in environments of unsuitable hosts would not materially weaken the foregoing contention that these oviposition responses are examples of behaviour promoting species survival. Meanwhile it may be remarked that the situation is complicated since the exact environmental conditions under which pronounced egg resorption occurs are by no means well defined. Thus it has been indicated in the preceding experiments that freshly emerged females, fed honey but held without hosts for the first 15 days of life at 80° F, show approximately 65%

TABLE VI

Further effects of host environments on egg regression in ovaries of *Leptomastix*

Type of environment	Percentage of eggs regressed at age:	
	15 days	25 days
Series J	60.0	64.3
K	3.3	2.8
L	0	0
M	2.6	8.2

resorption of all eggs produced within this period. At other times the isolation of groups of females under apparently identical conditions has produced a virtually total regression of the ovaries after 15 days without hosts. When such females were then supplied with heavy populations of *Pl. citri* no progeny resulted from the first seven or eight days of exposure since during this interval the ovaries were being reactivated to produce mature eggs for deposition. If this behaviour is compared with that reported for female *Leptomastix* first given access to *P. maritimus* etc. in the experiment of Table 6, then clearly the behaviour of the latter has the better survival value. Such observations further emphasize the need for caution in the interpretation of this parasite's behaviour towards the various hosts.

Conclusions and Discussion

Preceding experiments show that the oviposition response of *L. dactylopii* is released by stimuli present in *Pl. citri* and various other mealybugs. Some of the latter coccids are often found in the same habitats as the parasite's only authentic field host, and the continued failure to rear the encyrtid from field samples of any mealybugs other than *Pl. citri* clearly does not mean that oviposition does not occur in them. Rather the evidence suggests that its incidence is not appreciated because of the difficulties of finding and identifying in these mealybugs the immature stages of *L. dactylopii* destroyed by the demonstrated immunity reactions of *P. adonidum* and *P. maritimus* etc, since oviposition in the latter species has been observed in Southern California citrus groves. It would be somewhat surprising if oviposition which takes place easily in mixed host colonies in laboratory containers did not occur also when the mealybugs happen to be found together on a cacao pod, citrus fruit etc. The establishment of such crop monocultures by man has produced environments in which *Pl. citri* is associated with other mealybugs on the same plants and in many respects this can be considered as artificial as any grouping in a laboratory.

Thus the fact of field oviposition to an unknown extent in mealybugs unsuitable for progeny development cannot be seriously doubted. It is the interpretation of this behaviour that is not so obvious. In all experimental studies of the past twenty years on host selection by parasitic Hymenoptera ovary physiology has received scant attention, and for reasons of simplicity of procedure workers have used the technique of brief confinements of the various hosts with ovipositing females of known age. The investigators have been "taking a slice" of ovary activity and then assessing the manner in which the female parasite distributes, or disposes of, such released eggs under the controlled conditions. An attempt has been made to show by the foregoing experiments that to evaluate this behaviour without knowledge of the sequences of egg production and disposal in the female results in an inadequate description and unsatisfactory explanation. It is reasonable to regard all activities of the female hymenopterous parasite as at least complementary to, if not subordinate to, the primary function of oviposition in hosts capable of producing fertile offspring; so that the periodic egg laying by *Leptomastix* in hosts unsuitable for progeny development is essentially a type of release process whereby oogenesis continues uninterrupted and ripe eggs are constantly available for insertion in hosts suitable for progeny development whenever they are encountered. In terms of the Lorenz school of instinctive behaviour the action would perhaps be called an overflow activity (Armstrong 1950) as suggested by Finlayson (1950) for the bethylid *Cephalonomia*. The classification of hosts as suitable and unsuitable is obviously one of great convenience for the student of parasite behaviour but

enough has been said to indicate that in this case it is not entirely correct. Flanders (op. cit.) has theorized that egg resorption is a phenomenon common to most Hymenoptera, and there can be no doubt that the complex egg maturation —egg resorption processes must be given weight in assessments of host suitability. In the present instance the behaviour of *L. dactylopii* of limited oviposition in hosts unsuitable for progeny development meets the decisive and critical test of serving to promote species survival as the loss of individual eggs is a sort of by-product essential for a continuous egg maturation sequence throughout the life of the individual female. Of course, from an evolutionary viewpoint no behaviour pattern is static and one might speculate that the present host-parasite relationships represent a stage where an originally polyphagous parasite has become virtually monophagous as a consequence of an oviposition response becoming limited to more specific stimuli, coupled with physiological resistance in some of the host species.

Earlier remarks have indicated that in *L. dactylopii* the distinctions between the processes of habitat selection, host selection, and host suitability are not easily defined, so much so that use of this trinity as a description of the behaviour may be little more than a convenience for the investigator. The term "habitat" is always somewhat loosely used in entomological literature. With hymenopterous parasites especially the limits of these habitats have rarely been given although in behaviour studies with these insects the latter are referred to as being "attracted to" or "entering" certain types of environments in the form of the plants etc. in which the hosts live. A parasite's habitat might be defined as an area possessing a certain uniformity of vegetation or other qualities, and some such definition is necessary because the type of behaviour under discussion is largely a problem in orientation. What occurs in a case such as *Leptomastix* in a cacao plantation is that the newly emerged insects find themselves in a place, the "niche" or local environment, which is generally very favourable to their continued life since the mealybugs *Pl. citri* are very probably present in the immediate vicinity while others such as *P. adonidum* may also be close at hand. How dispersal of the females is effected from this initial favourable adaptive environment determines what host plants and insects will later be encountered. Precisely what these extrinsic stimulus foci are, and what courses of movement are followed with respect to them, were practical aspects beyond the scope of this investigation.* They will obviously depend on the organic equipment characteristic of the species. Orientation from a distance may be by olfactory responses to chemical stimuli from other cacao plants followed by close range searching of those for the actual mealbug hosts, but this analysis is simple conjecture.

Leptomastix has been recorded from *Pl. citri* infesting the nine plants *Paeonia*, *Ficus caricia* L., *Cassia splendens*, *Sechium edule* (Jacq.) Sw., *Glycine max* (L.) Merr., *Solanum melongena* L., *Euphorbia pulcherima* Willd., *Theobroma cacao* L. and *Citrus* spp., representing the eight families Ranunculaceae, Moraceae, Leguminosae, Cucurbitaceae, Solanceae, Euphorbiaceae, Sterculiaceae, and Rutaceae. Certain attractants may be characteristic of this group of plants with types as diverse as soybean, fig, cacao and citrus. Whether one considers the plants as botanical entities or as heterogenous chemical environments the delineation of a homogeneous plant habitat is clearly a formidable task. Possibly the females are sensitive to stimulation by many unrelated compounds, as sug-

*To the writer's knowledge this type of information is not available for any entomophagous insect.

gested by Dethier (1951) for some phytophagous insects, and an initial random-like wandering is followed by orientation in odor-bearing air currents.

All the host plants cited for *Pl. citri* and *Leptomastix* are cultivated by man and the normal "wild" habitat of the parasite is unknown. This situation furnishes an interesting comparison with that reported by Nishida (1955, 56) for the braconid *Opius fletcheri* Silv., an introduced parasite of the melon fly *Dacus cucurbitae* in Hawaii. This fly infests at least 36 species of plants in 12 botanical families, and some are presumed unattractive to *O. fletcheri.* Nishida presented suggestive experimental results on close range attraction of the female braconids to the medium in which the host fly larvae occur but noted wide discrepancy between field and laboratory data so that attractiveness of the host habitat could not explain differences in the parasitism of melon fly larvae in various field plants. Most breeding of *D. cucurbitae* in Hawaii is stated to occur now in cultivated areas in which parasitism is low while contiguous wild areas with the host plant *Momordica* often show high parasitism. Insecticidal treatments could not account for the low parasite populations and Nishida considered the cultivated areas of unattractive to *O. fletcheri* adults partly because of high light intensities. Whatever the cause, the implication is that dispersal of the adult braconids from the *Momordica* wild hosts is very limited despite the nearby presence of heavy host larval populations in the cultivated crops.

Such examples are typical of the sparse data available on the movements of entomophagous insects in their natural environments. Pending increased knowledge of these movements the process of habitat selection in the sense proposed by the cited authors would seem to merit only a provisional acceptance. Laing (1937) has pointed out that there are no formal demonstrations in the literature of the claim that parasitic insects are attracted first to certain types of environment independently of host presence, and she then attempted to show this behaviour pattern in *Mormoniella vitripennis* and *Alysia manducator.* The findings with the former parasite were not substantiated by Edwards (1954-b) whose results confirmed earlier work by Jacobi. It is, moreover, noteworthy that the efforts of these and other workers have been concerned with close range orientation of the adult parasites to the host area or habitat under controlled laboratory conditions and the problem of distance orientation has been virtually ignored.

It has been stressed by Schneirla (1953) that an effective behaviour study must give adequate consideration to the organic setting of the behaviour and also to the typical environment in which the act runs its course. The preceding observations on some phases of the oviposition of *L. dactylopii* lend support to the view that this approach is essential for a satisfactory understanding of the problem of host specificity.

Summary

The problem of host preferences in the encyrtid *Leptomastix dactylopii* How., a parasite of third nymph and adult *Planococcus citri* (Risso) mealybugs, is examined.

Field records indicate the parasite is monophagous. Laboratory experiments in small containers showed this is not the result of an oviposition response to specific releasing stimuli in the normal field host since oviposition by 48 hour old females was common in various other mealybug species. This occured in pure and mixed cultures even when brief exposures of one hour were used. Under these conditions egg laying was frequent in *Pseudococcus adonidum* L., but less so in *P. maritimus* (Ehrh) and *Phenacoccus solani* Ferris.

Parasite progeny production in *P. adonidum* and *P. maritimus* is negligible

but with *Ph. solani* the parasite maintains its population. Following conventionally recognized processes of host preference dynamics the former two hosts are classed as unsuitable.

Processes of egg maturation and resorption in the female were examined during variable confinement of the adults in microenvironments of different mealybugs. It was shown that egg resorption is associated with the absence of hosts, that it rarely occurs in the presence of adequate populations of the normal field host (*Pl. citri*), and finally that it occurs only on a very minor scale in the sustained presence of the unsuitable hosts *P. adonidum* and *P. maritimus*. It is concluded that the periodic oviposition in hosts unsuitable for progeny development can be interpreted as serving to promote species survival as the release or resorption of eggs is essential for a continuous egg maturation sequence throughout the life of the female. From this standpoint the validity of classifying hosts as suitable and unsuitable is questioned.

The bearing of the observations on the general problem of host specificity in entomophagous insects is briefly discussed.

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Storage of Preserved Insect Specimens[1]

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Several methods of storing insect specimens in liquid preservatives have been used at the Forest Biology Laboratory at Victoria, all of them unsatisfactory to a varying degree. The method described herein was devised by the author and has proved successful during the past year.

Homeopathic vials approximately 62 mm. overall outside length x 15 mm. greatest outside diameter x 11 mm. inside neck measurement, with 000 rubber stoppers, are the most suitable size for insect specimens. The different stages of nearly any of the species of insects encountered by the Forest Insect Survey can be easily accommodated in a single vial of this size. Small shell vials may be used for double mounts when tiny insects are involved which might otherwise be lost in the larger vials. For material too large for the 11 mm. neck of the homeopathic vial, shell vials 65 mm. x 15 mm. can be used with serum sleeve-type stoppers. All but mass collections and a few of the larvae can be preserved in these sizes. Both types of rubber stoppers are satisfactory, although the sleeve type requires more effort to put on and seal, and also conceals the top of the vial. Air bubbles can be removed from the latter by inserting a hypodermic needle through the top of the stopper.

[1]Contribution No. 448, Forest Biology Division, Science Service, Department of Agriculture, Ottawa, Canada.

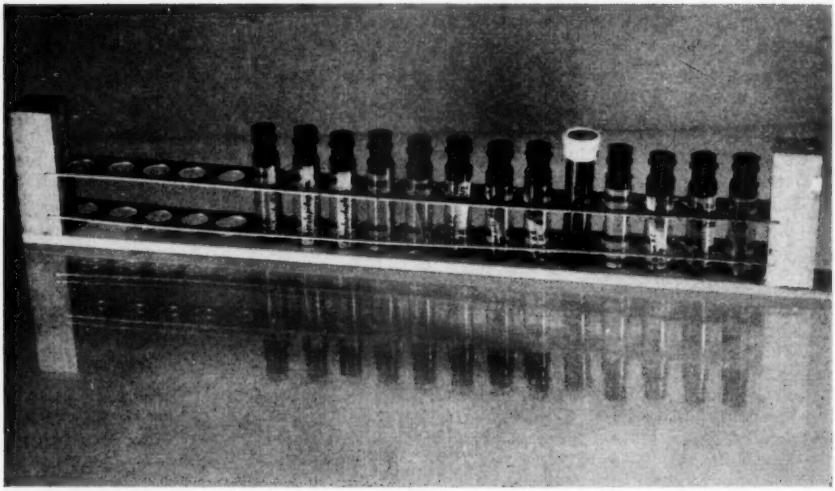

Figure 1. White pine and aluminum rack holding specimen vials.

The wood and metal racks (Fig. 1) for holding these vials are designed for storage in standard American Museum insect cabinets with custom shelves; each rack holds 18 vials. Outside measurements are 18¾″ x 1″ x 3¼″; thus 17 racks may be stored on each shelf, or a total capacity of 3060 vials may be obtained in a 10-shelf cabinet. The racks are made of white pine and 14-gauge utility aluminum. White pine is a suitable wood because it is light weight, relatively free of slivers, and is soft enough to yield to the nails and metal without splitting. Each rack requires one length of wood 18¾″ x 1″ x ¼″, two blocks of wood 1″ x 1″ x 3″, and two strips of metal 16¼″ x 1″. It is preferable to have the wood well dressed before cutting into small lengths. The metal strips are punched with ⅝″ holes down the centre, approximately ¼″ apart, leaving ¾″ at each end. The aluminum usually does not require any smoothing after cutting and punching. The blocks must have two 1″ slots sawed to a depth of ¼″ across one 1″ side, one of them ½″ from an end, the other 1½″ from the same end. These slots must be wide enough to accommodate the 14-gauge aluminum; the thickness of the average saw blade is adequate.

To assemble, ½″ finishing nails are used for fastening the blocks to the wood strip. One block is nailed upright on the extreme end of the strip, another block upright on the same side 1″ in from the other end. The slots in the blocks must be facing each other, with the ½″ margins of these blocks next to the base. Two nails are sufficient to hold each block but for added strength glue may also be used. When the glue has hardened, two aluminum strips are inserted in the exposed slots. If the size of the slots is correct the metal pieces should fit without too much effort, and glue can again be used for added stability. The underside of the punched metal should remain down to avoid possible rough edges. It is essential that the holes in the two aluminum strips be correctly aligned as there is not much tolerance when the vials are placed in them. At Victoria the individual pine and aluminum pieces are purchased locally, ready cut, and assembled by laboratory personnel. The approximate cost of one rack is 45c, of which one-third is for raw material.

These racks offer numerous other advantages. The use of a single mount makes for easier preparation, visibility, and handling of specimens. The material is visible from all angles and the complete rack may be quickly scanned. If required, individual vials can be revolved easily without removal. Although the vials are simply lifted in or out of their holes, it is nearly impossible for them to slide about or fall out unless the rack is tipped completely upside down. The plain construction of the rack and its convenient capacity allow for fullest use of storage space, and location and type of rack labels can be adapted for the immediate requirements. The tab end of the rack is not necessary, but provides a convenient grip. Simplicity and economy in construction could be considered of prime importance. The approximate weight of an empty rack is 4½ oz., and a full one is about 10 oz. more.

(Received February 11, 1958)

Note on Specific Gravity of Haemolymph of *Melanoplus bivittatus* (Say) and *Melanoplus mexicanus* (Sauss.) (Orthoptera: Locustidae)[1]

By H. L. House and June M. Stephens[2]
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It was necessary to know the specific gravity of the haemolymph, or blood, of grasshoppers for certain investigations on insect immunity, This information is not given in reviews on the physical properties of insect haemolymph (Rapp, 1947; Buck, 1953). Determinations of specific gravity were made by the technique developed by Lowry and Hunter (1945) and used on insects by Baldwin and House (1952). Nine males and 11 females of *Melanoplus bivittatus* (Say) and 11 males and nine females of *Melanoplus mexicanus* (Sauss.) were used after they had fed in the laboratory for three days on lettuce and dry dietary components. The mean specific gravity and the standard deviation for *M. bivittatus* was 1.0271 ± .0043, 1.0262 ± .0046, for the male and 1.0281 ± .0039 for the female; for *M. mexicanus*, 1.0261 ± .0023, 1.0257 ±.0021, and 1.0264 ± .0025, respectively.

There was no significant statistical difference ($P < .01$) in specific gravity between the male and the female of either species, or between the two species. However, the specific gravity was greater than that of another species of Orthoptera, *Periplaneta americana* (L.), the American cockroach: Yeager and Fay (1935) reported its specific gravity as 1.0162.

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Internal Changes in the Female Mountain Pine Beetle, *Dendroctonus monticolae* Hopk., Associated with Egg Laying and Flight[1]

By R. W. Reid[2]

Studies of the mountain pine beetle by DeLeon (1934), Evenden *et al.* (1943), Hopping and Mathers (1945), have shown that females frequently establish more than one egg gallery each season. Recent studies by the author indicate that females commonly leave their first egg galleries after a period of 2-3 weeks and fly to another tree where the second egg galleries are established.

It has been pointed out by Chapman (1956, 1957) that specific internal changes can be associated with certain activities of the adult of *Trypodendron lineatum* (Oliv.) and other scolytids. This present paper describes some internal changes which are associated with the flying stage and the egg-laying stage of the female mountain pine beetle. These changes are most apparent in the metathoracic muscles, the fat body, and the reproductive system.

The insects were secured in wax to facilitate handling, then were frozen and sectioned to the required depth. They were stored in formol-saline solution and later photographed. All the insects used for these illustrations had been preserved in formol-saline solution for several months prior to sectioning.

The internal condition before, during, and after egg laying is shown in Figs. 1-10. The works of Hopkins (1909) and Richmond (1935) were used to name body parts. Names of the muscles were interpreted mainly from Rüschkamp (1927).

The points of origin and insertion of the indirect flying muscles are as follows: metathoracis medianus (Bauer) (a) originates on the postphragma and is inserted on the prephragma; lateralis posterior (b) originates on the lateral expanded area of the postscutellum and is inserted on the scutal lobe; lateralis anterior (c) originates on the anterior portion of the sternum, adjacent to the median line, and is inserted on the anterior disk and the anterior lobe of the prescutum; lateralis medius (d) originates on a sclerotized disk which in turn is secured by a short ligament to the metacoxa very close to its sternal articulatory point and is inserted partly on the prescutal lobe and partly on the scutal lobe. In reference to the lateralis medius, Jackson (1928) describes a somewhat similar muscle in the weevil *Sitona hispidula*. This muscle, which is called the musculus lateralis metathoracis secundus (of Stellwag) is described as being attached to the anterior scutal lobe (prescutal lobe of Hopkins) and "ventrally is inserted in a muscle disk which is attached to the posterior edge of the sternum, not far from the middle line, near the inner angle of the coxa."

The points of insertion and origin of the most prominent direct flying muscles are as follows: extensor alae anterior (e) are inserted on the pleural clavicle disk, the two anterior muscles originating on the sternum and the two posterior muscles originating on the anterior rim of the metacoxa approximately halfway between the pleural and sternal coxal articulating points; extensor alae posterior (f) is inserted on a sclerotized disk in the pleural region and originates inside the metacoxa. This sclerotized disk is visible through the membranous epidermis between the epimeron and the lower margin of the scutellar process and is attached by ligaments to the flexor plate (of Hopkins). This sclerotized disk is apparently absent in the weevil *Sitona hispidula*. According to Jackson (1928) the extensor

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alae posterior muscle is attached to the pronator muscle disk (pleural clavicle disk of Hopkins).

When young adults emerge from their brood logs they have large columnar metathoracic muscles, essential for flight. The major metathoracic muscles are illustrated in Figs. 1 to 5. Figs. 1 and 2 show progressively deeper sagittal sections and Figs. 3 to 5 show progressively deeper frontal sections.

The outer group of muscles shown in Fig. 1 are the extensor alae anterior (e) and the extensor alae posterior (f). In Fig. 2 the extensor alae anterior and posterior muscles have been removed to expose the lateralis anterior (c) and the lateralis medius (d). Portions of the lateralis posterior muscles (b) can also be seen. Fig. 3 shows portions of the metathoracis medianus (a) but only cross sections of the lateralis posterior (b) and the lateralis medius (d). The extensor alae anterior and posterior muscles are attached below the region exposed. In Fig. 4, which is close to a median frontal section, most of the metathoracis medianus muscles have been removed. Cross sections of the lateralis medius, lateralis anterior, and the lower portions of the lateralis posterior are visible. The extensor alae muscles are not evident since the section illustrated in Fig. 4 is not deep enough. Fig. 5 represents a deep frontal section in which only cross sections of ventrally attached muscles are visible. This includes all the large metathoracic muscles except the metathoracis medianus and the lateralis posterior.

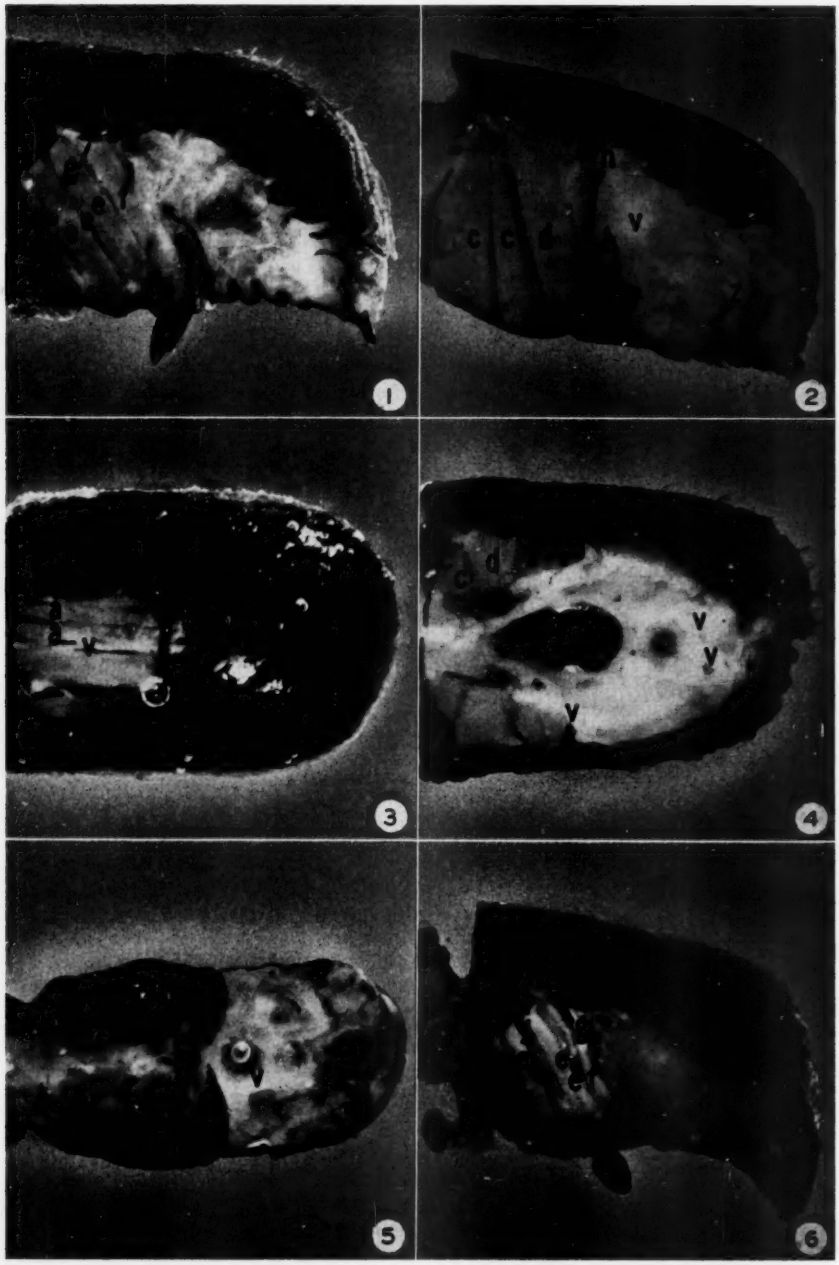
In addition to the large muscles discussed above, young adults in this stage have a conspicuous fat body, particularly evident in the metathorax and abdomen. In the abdomen it appears to occupy more space than any single organ. The portion of the mid intestine contained in the metathorax is embedded in fat.

The reproductive system of young adults in the flying state is reduced and occupies only a small portion of the metathorax and abdomen. The reproductive system prior to egg laying is shown in Fig. 9 and during egg laying in Fig. 10. The ovarioles are attached anteriorly to the prephragma of the metathorax by the suspensory ligament (t). The point of attachment is immediately below the metathoracis medianus muscle attachment. Suspensory ligaments from both pairs of ovarioles are joined together in a broad tissue which is attached to the prephragma.

In the flying stage the hind intestine frequently contains food particles but the rest of the digestive tract is empty.

When they emerge from their parental brood galleries, young adults fly to another tree and establish themselves under the bark. Following mating, they commence to extend their galleries up the tree, and lay eggs in small niches along the sides of the egg galleries. If these females are examined during egg laying, many internal changes will be apparent. The most noticeable is in the metathorax where the large muscles have degenerated and are now ribbons of tissue. Partial degeneration of the metathoracic muscles is illustrated in Fig. 6, and the maximum degeneration, which occurs at the height of egg laying activity, in Fig. 7. The muscles at this stage are so much reduced that they are not evident. The degeneration is further illustrated in Fig. 8 where a lateralis medius muscle from a young female in condition for flight (d2) is compared with one dissected from a female at the height of egg laying (d1).

There is an extensive reduction in the volume of fat in egg laying females as compared to adults in condition for flight. This is shown in Figs. 6 and 7. The reproductive system in the egg-laying females is the most conspicuous internal element. The ovarioles take up much of the abdominal cavity (Fig. 7). Fig. 10 shows the reproductive system from an egg-laying female. The over-all increase in size is evident when compared with Fig. 9 which shows the reproductive



Figs. 1 and 2. Sagittal sections at various depths through a young female in condition for flight.
Figs. 3 to 5. Frontal sections at various depths through a young female in condition for flight.
Fig. 6. Shallow sagittal section through a female in the egg-laying condition. Partially degenerated metathoracic muscles are exposed.

system of a female in condition for flight. The ovarioles, while still secured in pairs by a suspensory ligament, are no longer closely attached throughout their length. The degenerated epithelial cells (corpora lutea) can generally be observed as a faint yellowish accumulation in the extreme lower end of the ovarioles (not

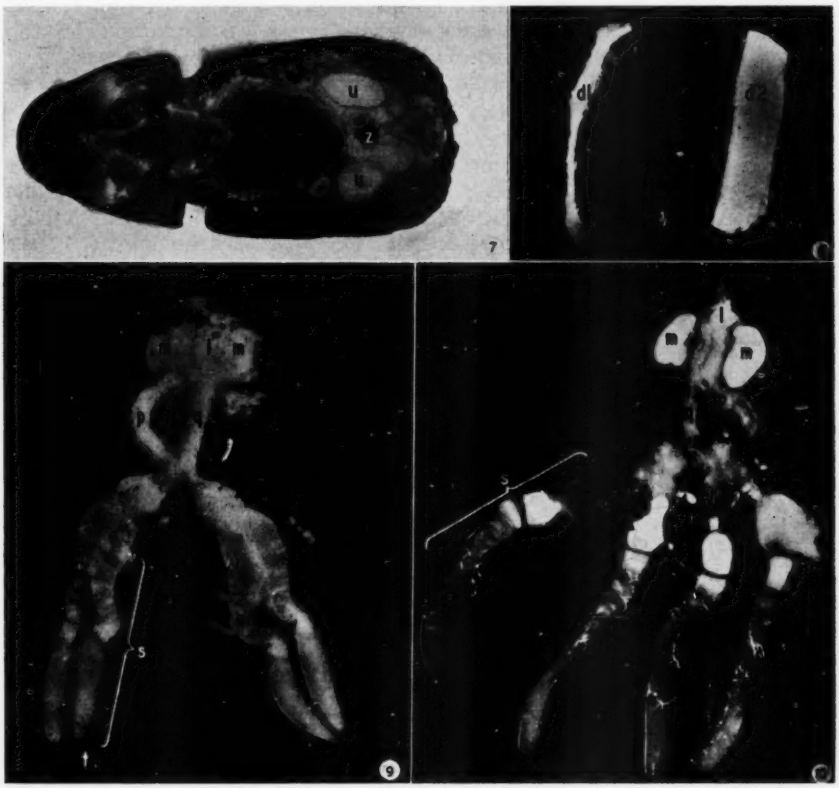


Fig. 7. Frontal section, close to median, through a female in the egg-laying condition. Note absence of metathoracic muscles.

Fig. 8. Illustrating degeneration in the lateralis medius: d1 dissected from a female in the egg-laying condition; d2 dissected from a female in the flying condition.

Fig. 9. The reproductive system of a young adult in the flying condition (total length 2.7 mms.).

Fig. 10. The reproductive system of an adult in the egg-laying condition (total length 5.3 mms.).

Legend for Figures

Muscles:

(a) metathoracis medianus; (b) lateralis posterior; (c) lateralis anterior; (d) lateralis medius; (e) extensor alae anterior; (f) extensor alae posterior.

Sclerites and apodemes:

(g) sclerotized disk; (h) postscutellum; (i) furca; (j) pleural clavicle disk.

Reproductive system:

(l) vagina; (m) collaterial gland; (n) seminal receptacle gland; (o) seminal receptacle; (p) bursa copulatrix; (q) median oviduct; (r) lateral oviduct; (s) ovariole; (t) suspensory ligament; (u) Oöcyte.

Miscellaneous

(v) fat body; (w) proventriculus; (x) crop; (y) ventriculus; (z) hind intestine.

visible in Fig. 10). The bursa copulatrix (p) of females at the height of their egg laying is frequently enlarged and turgid in appearance. The heavily sclerotized seminal receptacle (o) and receptacle gland (n) are visible in Fig. 10. The colleterial glands (m) enlarge considerably in egg-laying females but are not commonly as turgid in appearance as Fig. 10 suggests.

The female ingests considerable quantities of wood and bark fibre while excavating the egg gallery. The digestive tract is distended, particularly the crop (x) and ventriculus (y). The ventriculus now occupies most of the metathorax (Fig. 7).

If these females are allowed to complete the egg gallery and are examined prior to their re-emergence, they appear similar to the young flying adults described earlier. In the metathorax large "columnar" muscles are once more apparent. The fat body becomes conspicuous again. The reproductive system is reduced and resembles that illustrated in Fig. 9. Evidence of former activity in the reproductive system can frequently be interpreted by the presence of the corpora lutea. The digestive tract is similar to that described for the young flying adult, with the ventriculus and crop reduced to their previous size. The female is once more in condition for flight.

Acknowledgements

The writer wishes to thank P. S. Debnam for taking the photographs. The assistance of other members of the Calgary Forest Biology Laboratory in reviewing the mansucript is hereby acknowledged with thanks. Thanks are extended to J. A. Chapman, Forest Biology Laboratory, Victoria, B.C. for his helpful suggestions.

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A Redescription of the Female and First Descriptions of the Male, Pupa and Larva of Prosimulium Flaviantennus (S. and K.) with Notes on the Biology and Distribution

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The female of *Prosimulium flaviantennus* (Stains and Knowlton) was originally described from Logan Canyon, Utah in 1940. In 1943 the same authors figured the genitalia of a male they considered to be of this species. No actual description of the male was given, and nothing on the biology was reported.

During the spring of 1956 and 1957 large numbers of larvae and pupae of the species were collected by the writer. Reared pupae provided adults of both sexes. A redescription of the female and first descriptions of the male, pupa and larva, and notes on the biology and distribution of this species are presented below.

Prosimulium flaviantennus (Stains and Knowlton)

Simulium (*Eusimulium*) *flaviantennus* Stains and Knowlton, 1940, Ann. Ent. Soc. Amer., 33(1): 79-80; Figs. E, H. (female).

Prosimulium flaviantennus (Stains and Knowlton), 1943, Ann. Ent. Soc. Amer., 36(2): 262; Plate I, Figs. 7, 11; Plate III, Figs. 130, 131 (female, male). Smart, 1945, Trans. Roy. Ent. Soc. London, 95(8): 497. Peterson, 1955, Proc. Utah Acad. Sci., Arts and Letters, 32: 114.

Simulium flaviantenna Stains and Knowlton. Vargas, 1945, Inst. Salub. y Enferm. Trop., Monografia Num. 1: 137.

Female. General color dark brown to black, legs yellow. Length: Body, 3.5 - 4.0 mm.; Wing, 3.8 - 4.3 mm. Head dark brown to black, covered with moderately long, yellow hair, a few stout, erect, black hairs at posterior and lateral margin of eye. Frons wide, divergent above, at apex of eyes about twice as wide as at narrowest point and about equal to width of ocular notch; covered with moderately long, decumbent, yellow hair. Clypeus brown, lighter than frons, longer than wide, with ventro-medially directed yellow hair and a few stout, erect, dark hairs on the ventro-lateral margins. Antenna eleven segmented, bright yellow, with short, proclinate, yellow hair intermixed with some short, stout, dark hair especially on basal segments and outside lateral surface of other segments; flagellum about five times as long as scape and pedicel. Palpus brownish-yellow, with proclinate, yellow hair. Mandible with 51-53 serrations; galea of maxilla with about 39 retrorse teeth. Median space of buccopharyngeal apparatus of a broad U-shape, squared at the base, lacks teeth or spines, dorso-lateral arms moderately sclerotized. Pronotum lighter than scutum, with long, erect, yellow hair. Proscutum with long, recumbent, yellow hair. Scutum dark brown to black, covered with recumbent, yellow hair, and with longer and more erect hair on posterior margin. Scutellum yellow, with long, erect, yellow hair. Postscutellum bare, shining brown. Pleuron dark brown, lighter than scutum; pleural membrane infuscate; pleural tuft of long, yellow hair. Wing veins yellowish; hair on stem vein and undersurface of subcosta yellow, base of costa with yellow hair predominant. Radial-sector forked apically, [not single as indicated in original description]. Fringe of calypter and alar lobe yellow. Halter yellow, with fringe of short, yellow hair. Legs yellow; coxa and tarsus somewhat browned, with yellow hair intermixed with

[1]The research on which this paper is based was financed in part by a grant from the University of Utah Research Fund.

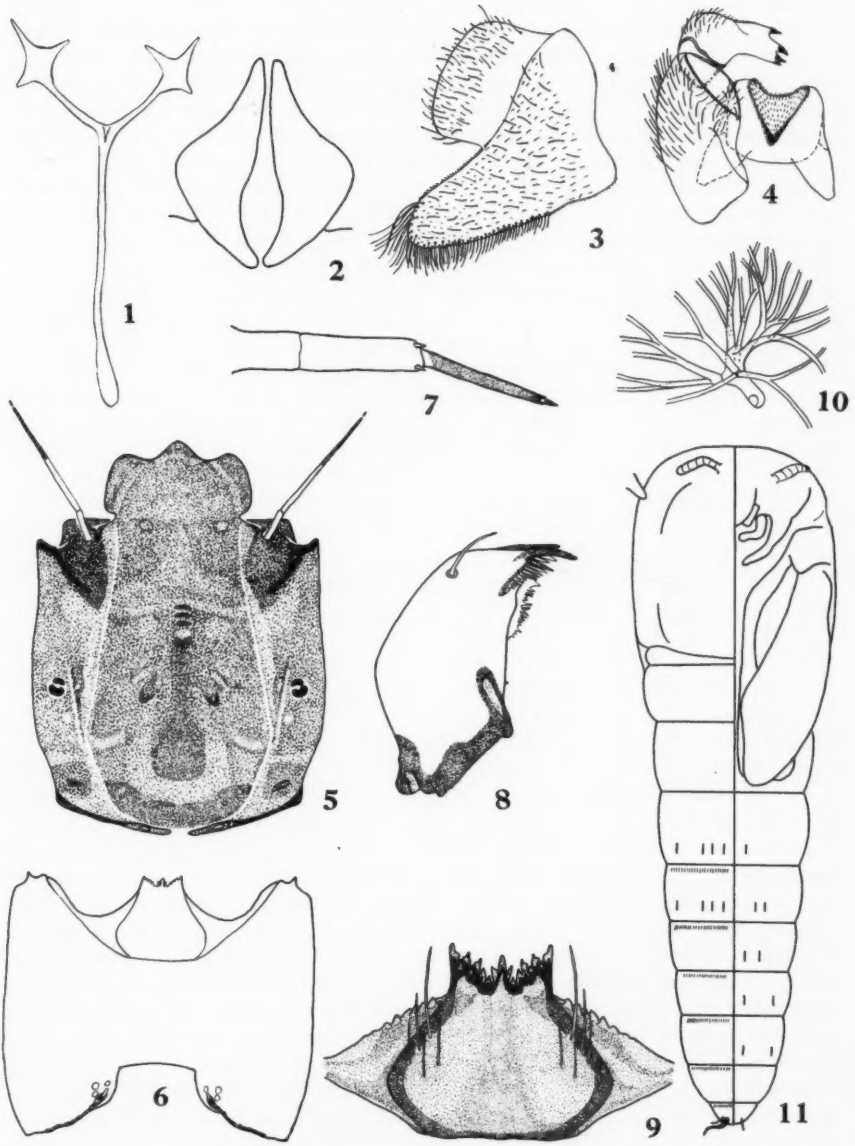
dark hair on tarsus; inner distal surface of front femur with several long, stout, dark hairs; hind basitarsus about six times as long as greatest width; second hind tarsus about three and one-half times as long as greatest width. Claws simple. Abdomen infuscate dorsally, more yellowed on basal section ventrally; with short yellow hair. Basal scale yellowed, with fringe of long, fine, yellow hair. Anal lobe and cercus as in figure 3. Ovipositor flaps broad, tapering distally, lightly sclerotized on basal medial margin; flaps not reaching tip of anal lobe (figure 2). Genital rod as in figure 1.

Male. Size and general body color as in female, but abdomen slightly darker. Posterior and undersurfaces of head with long, erect, pale yellow hair. Frons and medial marginal area between eyes with erect, pale hair. Clypeus dark with moderately long, erect, yellow hair. Antenna yellow with fine, short, pale hair. Palpus brown, the two distal segments often lighter, segments with yellow hair. Thorax essentially as in female. Hair on stem vein, base of costa, alar lobe, and fringe of calypter yellow. Halter pale yellow. Legs essentially as in female, coxae brown, inner surface of hind femur browned distally; hind basitarsus about four times as long as greatest width; second hind tarsus about three times as long as greatest width. Basal scale of abdomen dark brown to black, with fringe of long, pale yellow hair. Abdominal tergites dark brown with narrow, pale margins posteriorly, covered with short, pale hair; sternites usually lighter, with long, pale yellow hair. Basistyle large, considerably longer than dististyle; dististyle wide at base, narrows abruptly at about one-half its length, somewhat truncate apically with three to six (average four) apical spines (figure 4).

Allotype: male (reared), Logan Canyon, elevation 6,000 feet, Cache County, Utah, May 26, 1957, B. V. Peterson. In collection of University of Utah, Salt Lake City.

Pupa. Length 4.5 - 6.0 (average 5.5) mm. Respiratory organ 2.0 - 2.5 mm., usually slightly longer than dorsum of cephalothorax, with 20 - 26 (average 25) irregularly branching filaments arising from five basal groups that in turn arise from a short knob covered with minute, closely set spines (figure 10). Dorsum of cephalothorax nearly smooth; trichomes single. Tergites 4-9 with a single row of short, fine, closely placed spines on anterior margin; tergites 3-4 with eight larger hooks on posterior margin. Terminal spines recurved posteriorly, somewhat divergent apically, with a short seta at base of each anteriorly. Sternite 3 with two hooklets on posterior margin; sternites 4-5 with four ventro-lateral hooklets; sternites 6-7 with four hooklets, two mesal and two lateral; sternites 8-9 bare except for scattered setae. Cocoon of loosely woven sock with a definite floor that extends forward about two-fifths the total length; cocoon enclosing all of pupa except tips of filaments (figure 11).

Larva. Mature specimens 9.0 - 9.5 mm. long. Head capsule dark reddish-brown, faintly mottled with lighter areas; frontoclypeal plate with a light U-shaped area posteriorly and medially, with a light lateral spot on each side appearing as oblique arms of the U; three dark and one light anterior medial head spots closely situated to numerous small, medial, dark head spots placed closely together so they appear as a single elongate, triangular, dark area that broadens posteriorly. A small, light spot, from which a small seta projects, occurs on each side of frontoclypeal plate anterior and mesad of base of antennae. Epicranial plate dark, variously mottled with lighter areas; eye spots set close together in small, light circular area; two light, dorso-lateral spots occur posterior to eyes, and a narrow, light, oblique line occurs dorsal to the eyes



Prosimulium flaviantennus (S. & K.). Figs. 1-3, female. Fig. 1. genital rod; Fig. 2. ovipositor; Fig. 3. anal lobe and cercus. Fig. 4. male genitalia. Figs. 5-9 mature larva. Fig. 5. head capsule, dorsal; Fig 6. head capsule, ventral; Fig. 7. antenna; Fig. 8. mandible; Fig. 9. submentum. Figs. 10-11 pupa. Fig. 10. respiratory filaments; Fig. 11. pupa: left side, dorsal; right side, ventral.

(figure 5); ventral surface with a light, narrow, inverted, triangular area that extends forward from apical margin of throat cleft to base of submentum. Throat cleft a shallow, rectangular shape, nearly twice as wide as long, extends anteriorly about one-third the distance to the base of submentum (figure 6). Suboesophageal ganglion a light grey color. Submentum as in figure 9; lateral margins serrate but number of serrations often varies from side to side, average number is eight; three to five epicranial setae on each side. Distance from apex of outermost tooth of submentum to base of anteriormost epicranial setae on same side nearly equal to the distance between apex of outermost teeth. Mandible with small teeth having relative lengths of about 10 - 7 - 11, the first two teeth lightly sclerotized, the third tooth is more heavily so. Following and in line with these three teeth are 9 - 10 bristle-like teeth that are progressively shorter posteriorly. The inner subapical margin consists of a series of irregularly sized teeth 12-16 in number, often varying in number from side to side, the apical tooth being the longest and broadest (figure 8). Maxillary palp dark except for light apex; is slightly more than twice as long as greatest width at base. Relative lengths of antennal segments, from base to apex, 10 - 20 - 20 - 3; the two apical segments pigmented (figure 7). Cephalic fan with 28 - 34 rays. Pupal respiratory histoblast with 20 - 26 filaments. Abdomen of preserved specimens mottled gray with light intersegmental lines. Ventral tubercles absent. Anal gills of three simple lobes. Anal cross-piece heavily sclerotized, area between arms moderately so; dorsal arms slightly longer than ventral arms. Anal hooks 10 - 12 per row, in about 78 rows.

Distribution. Colorado: Fort Collins, elevation 5,100 feet, Larimer County, July 5, 1938 (M. T. James). Utah: Logan Canyon, Cache County, July 10, 1938 (D. E. Hardy and A. T. Hardy), (Type female, in U.S.N.M.); elevation 6,000 feet, May 26, 1957 (B. V. Peterson). Kanosh Canyon, Millard County, May 27, 1939 (G. F. Knowlton and F. C. Harmston). Leeds, elevation 2,750 feet, Washington County, June 21, 1941 (G. F. Knowlton and F. C. Harmston). Chalk Creek Canyon, elevation 6,800 feet, Summit County, May 31, June 2, 1956; June 2, 1957 (B. V. Peterson). Wyoming: Chalk Creek Canyon, elevation 7,000 feet, Uinta County, May 31, June 2, 1956; June 2, 1957 (B. V. Peterson); new state record.

Biology. This species has been collected at elevations from 2,700 feet to 7,000 feet. The larvae and pupae have been found only in small, spring fed streams varying in width from eight inches to three feet, and in depth from two to 24 inches. The immature stages are found in streams with much emergent vegetation, and they attach to the trailing grass, willow branches, or on small rocks. They are generally found in slow flowing areas of the stream, but have been collected in water with little perceptible movement to that with a current velocity up to 4.5 feet per second. Regions exposed to the sun seem to be preferred to shaded areas. The winter is passed in the larval stage, the larvae mature in early May or June. The time of maturity and pupation apparently depend upon the water temperature for they occur in water varying from about 60° - 72°F. at the time of emergence. The adults reach their peak of emergence about the end of May. This varies, however, with the altitude and the water temperature. There appears to be but a single generation per year in a given locality. Groups of adults of both sexes have been found resting during the heat of the day in a culvert pipe where it was shady, cool and moist. Adult females have been collected flying about humans, sheep and cattle during the cool morning hours, but have never been observed to bite and

none have been found that contained blood. The pupae occur in masses often an inch or more thick, and the entire mass is enclosed in long silk-like threads. Those larvae that mature and are first to pupate form the bottom layers of the mass. If the adult does not develop before the mass of pupae becomes too thick they have a difficult time working their way to the outside of the mass, and consequently many adults become trapped and die. On examining the remains of such pupal masses parts of trapped adults, including the head, legs and genitalia, and usually the cast larval head capsule and skin can be found. These fragments usually allow for species identification and thus aid the association of the larval, pupal and adult forms.

In some areas *Prosimulium flaviantennus* and *P. exigens* D. & S. have been found to form mixed groups. The larvae of both species mature at nearly the same time, and when they pupate form large mixed species masses. Occasionally *Simulium* (E.) *aureum* Fries, *S.* (*E.*) *sp.*, *S.* (*S.*) *venustum* Say and *S.* (*S.*) *tuberosum* Lund. have been found to form large intermixed masses of pupae with *P. flaviantennus* and *P. exigens*. These pupal masses serve as temporary shelters for several species of chironomid larvae that seem to move with ease among the black fly pupae and apparently live there as commensals.

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Notes on the Biology and Laboratory Colonization of *Wyeomyia smithii* (Coquillett) (Diptera : Culicidae)[1]

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Since the initial observations on the pitcher plant mosquito, *Wyeomyia smithii* (Coquillett), from 1901 to 1904 by Smith (1904), only limited additional contributions have been made toward the understanding of the biology of this species. Horsfall (1955) indicates that, aside from one 1913 citation and a brief reference to his own observations, all material summarized by him about this species was reported by Smith. For the past 50 years, mosquito workers have generally limited their observations on *W. smithii* to statements of seasonal development in nature, this usually being in conjunction with a more detailed regional study emphasizing the ecology of other mosquito species. The well-known specificity for the development of *W. smithii* only in the pitcher plant, *Sarracenia purpurea*, undoubtedly has precluded much in the way of laboratory investigations on this mosquito. However, during the summer of 1957, a large number of larvae of this species was found just north of Itasca State Park, Clearwater Co., Minn., and the opportunity presented itself to investigate the possibility of rearing *W. smithii* independent of the pitcher plant. It is the purpose of this paper to describe a method for the laboratory colonization of this mosquito completely free of any pitcher plant association and to make additional contributions to the biology of this species.

In the laboratory, larvae of *W. smithii* have been found to develop satisfactorily when up to 100 larvae are placed in a 100 mm. diameter finger bowl containing a light suspension of finely ground commercial rabbit food in distilled water. Whenever there is evidence of fouling of the water, this medium should be renewed. In this manner, in conjunction with the light and tempera-

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ture conditions stated below, larvae have been reared from hatching to pupation in 15 to 18 days, although a considerably longer time is usually required. In one group of 187 larvae, the first pupa appeared 16 days after hatching, 13 had pupated after 25 days, and 71, or 39 per cent, had pupated after 43 days. This rate of development is adequate for maintaining sufficient numbers of adults, but it would be desirable to determine the factors important to optimum rearing conditions for the larvae of this species. Numerous other workers have encountered this same phenomenon; they have brought larvae into the laboratory and observed that some larvae develop very slowly, taking months to mature, whereas others progress quite rapidly.

Without disregarding the possibility of an inadequate food supply for rapid larval development, preliminary studies were made on the effects of light, temperature, and aeration upon rate of larval growth. As a result, the most rapid and uniform growth of the individuals has been obtained to date in a container situated at approximately 80-90°F. and receiving constant illumination from a frosted 75-watt light bulb; no artificial aeration is provided for the water. When the most successful larval rearing was first obtained under this illumination at approximately one-foot distance, the result was attributed originally to the effect of the light. However, the heat from the bulb subsequently has been found to maintain an elevated temperature near the finger bowls of approximately 10°F. above the room temperature where the other larvae were being maintained. In establishing this laboratory colony, no attempt has yet been made to evaluate the exact light-temperature-food inter-relationships and it will await further study for this to be done. It is not surprising to find that, within limitations, rate of growth is proportional to water temperature; yet the photoperiod may well play a role in maintaining optimum rate of larval development.

Whenever aeration was employed, excessive larval mortality occurred and no increase in developmental rate was noted. Lloyd (1942) reports that in *S. purpurea* there are no stomata in the inner zones that occur below the lip of the pitcher. This would preclude any maintenance of a high oxygen level through the photosynthetic processes and tends to confirm the results obtained in the laboratory.

It is a well-known fact that *W. smithii* overwinters as larvae frozen in ice; this cold-hardiness enables this species to be stored for weeks or even months with arrested larval growth and negligible mortality at temperatures around 40-50°F. In this manner it is possible to synchronize the development of larger numbers of larvae and assure adequate adult populations for experimental purposes.

The behaviour of the larva coincides closely with that reported by Smith (1904) and other workers. Fortunately, as the fourth-instar larva nears pupation, it abandons its bottom existence and comes to the surface, as noted previously by Mitchell (1905), generally remaining suspended there for very long periods. At this point it is advisable to remove all such larvae to fresh distilled water with a minimum of nutrient material. If the larva is left to pupate in the original larval medium, quite often the pupa is found dying on the bottom of the bowl; however, there is negligible pupal mortality when pupation occurs in distilled water.

Pupa

All pupae are maintained in distilled water until emergence occurs. Since the pupal stage consistently lasts 5 to 6 days at room temperature (75-80°F.),

sufficient time is available for the unhurried transfer of the pupae to the emergence chamber.

Adult

The apparatus found to give consistently the best results for adult emergence and maintenance is as follows: A small jar of approximately 125 ml capacity (i.e., a small baby-food jar proved of excellent size and shape) is fitted tightly into a hole in a piece of corrugated pasteboard until the lip is flush with the upper cardboard surface. This jar contains about one inch of distilled water and a piece of filter paper trimmed so that it covers most of the inner surface of the jar, both above and below the water. In this manner, a moist surface as well as open water is offered to the mosquito for resting and oviposition. This apparatus is supported to avoid overturn and a wide-mouth quart jar is inverted over the open hole to rest on the upper surface of the pasteboard. A small piece of filter paper may be attached half-way up the inside of the quart jar to provide additional resting area. Once adult emergence has commenced, a small plastic vial cap with moist cotton and several raisins is placed on the pasteboard under the quart jar. This apparatus can be manipulated quite easily with a minimum danger of adult escape in view of the fact that the adults are relatively weak fliers.

Pupae may be added to the water in the small jar until the desired number is present. This worker has found that 20 to 40 individuals per jar have given excellent results. An encouraging feature in rearing this species is that the adults always have made a completely clean emergence. In nearly 300 adults that have emerged thus far, none has failed to make a successful flight from the water surface. The adults seem to select either the moist or dry filter paper as resting sites in preference to the sides of the quart jar and the pasteboard. When disturbed they make short flight sorties, but come to rest again as soon as possible.

The feeding, or absence of feeding, of *W. smithii* is one of the more significant findings of this work. On three separate occasions fertile eggs were obtained from adults that had had access to no material other than the distilled water in which the pupae had been placed. The females apparently can develop their full batch of eggs without partaking of any food. The addition of raisins to the chamber does prolong the adult life span, for it is felt that the adults do feed on the raisin juice and thereby possibly increase their vigor and subsequently their degree of mating. But, as will be enlarged upon later, the availability of food seemingly does not effect the ability of the female to mature her eggs and this species may now be added to the list of known autogenous stenogamic mosquitoes. The preponderance of opinions expressed to date has been that *W. smithii* does not feed on humans, and the above finding adds support to the statement of Smith (1902), "This is the Jersey mosquito for which I claim that it does not bite." There is still the possibility, however, that *W. smithii* may feed occasionally upon vertebrates other than humans.

Mating will occur within the confines of the quart jar and, judging from the percentage of fertile eggs and of inseminated females (Table I), this space must be adequate. Of 42 females dissected at death, 23 were shown to have sperm in at least one spermatheca. This is not to imply that all of the remaining 19 were infertile since the state of the spermathecae at dissection was sometimes too far deteriorated to permit accurate judgement as to the presence or absence of sperm. On two occasions this writer was fortunate enough to observe pairs in copulation. The female had positioned herself on the filter paper half-way up

the side of the quart jar with her body projected outward and downward at about a 30-degree angle from the horizontal. The male assumed an inverted position beneath her, with his forelegs grasping the forelegs of his mate, apparently suspending himself from her. The two remained in the act of copulation for 15 to 30 seconds. Then the male released his hold and flew away; the female remained in her original position. To attone for the reduced winter daylight hours, an additional 3 to 4 hours of artificial light were provided to make the effective day 12 to 13 hours long; no evaluation was made to see if this was necessary, and, aside from this, laboratory conditions prevailed throughout the rearings.

Oviposition commences on the fourth or fifth day after the emergence of the first females and continues sporadically as long as there are still females present in the colony. The eggs are laid during the daytime as well as the night, with a marked preference for oviposition from mid-morning until late afternoon. Smith (1904), on the other hand, noted that it was probable that egg-laying was done mostly at night. The ease with which the females will oviposit either infertile or fertile eggs upon open water under confined conditions makes it surprising that this has not been reported previously. Numbers of workers have reared out adults in the laboratory, but they perhaps have either killed them soon after emergence or else failed to notice the "pregnant" condition of the female 2 to 3 days after her emergence.

An estimate of the potential egg production per female has been derived by coupling the total number of eggs laid with the number of unlaid eggs found upon dissection of the abdomen of each female when she died. Reference to Table I reveals the possible productivity of *W. smithii*, bearing in mind that this is a determination based on laboratory-reared material and no supposition is made on the possibility of a second clutch being matured. Forty-two females were responsible for a total of 2162 eggs, 1169 (54.1%) of which were laid directly on the water, 147 (6.8%) of which were laid on moist filter paper above the water, and 846 (39.1%) of which remained in the abdomen of the female. A small number of infertile females were reared and dissected before they had a chance either to feed or oviposit. The following numbers of developed eggs were found in the seven specimens: 33, 40, 46, 50, 68, 79, and 106. The average of 60.2 eggs per female is in fairly good agreement with the average of 51.5 shown in Table I. The one individual with 106 ova represents an unusually large number, probably approaching the maximum possible. Smith (1904) recounted the finding of 75-100 eggs on a single leaf and said that it was scarcely probable that any one female of this species was capable of producing one hundred eggs of the large size of those in question. He attributed this output to at least two and possibly more individuals. The above figures, however, would indicate that such a production is at least theoretically possible from a single female.

The maximum longevity of adults of this species when given access to raisins was found to be approximately 18 days, although the majority of the individuals lived an average of only 6 to 9 days. When denied any raisins, no adults lived beyond 6 days.

Egg

The eggs are laid singly, preferably directly on the water surface, or occasionally on the moist filter paper above the water. Table I gives the distribution of the eggs between these two oviposition sites. These eggs are

TABLE I

Egg production of three groups of *Wyeomyia smithii* (Coq.) adults reared in the laboratory

Group	Number of females	Number known fertile	Eggs on water	Eggs on filter paper	Eggs in abdomen	Per cent of eggs hatched	Average number of eggs per female
1	9	8	121	52	251	82	47.1
2	20	10	630	36	254	86	46.0
3	13	5	418	59	341	69	62.9
Total	42	23	1169	147	846	79	51.5

not a result of a death-stress oviposition; there was absolutely no correlation between the finding of dead females and the concurrent appearance of eggs.

The individual chestnut-brown egg is provided with a longitudinal hydrophobic area along the slightly concave surface, which represents the ventral side of the developing embryo. This enables the majority of the eggs to float ventral side up at the water surface and often to gather together in loose agregations. Once an egg is pressed below the water surface, it sinks to the bottom, a thin film of air being revealed as a silvery region on the ventral surface. A definite chorionic sculpturing, present along this ventral region and inconspicuous on the other more dorsal portions of the egg, may well contribute to the ability of the egg to float.

The incubation period at room temperature is 3 days in most cases, with an occasional variation of one day on either side of this. By the end of 48 hours, fertile eggs can readily be distinguished from infertile eggs under the binocular dissection microscope; the chorion is transparent enough to allow the eyes, egg burster, and some larval hairs of the embryo to be seen. The eggs are allowed to remain on distilled water until they hatch; the larvae are transferred to the larval medium within the following 24 hours.

To the knowledge of this writer, this is the first report of a successful laboratory colonization of *W. smithii*. At the present time, successful production of fertile eggs has occurred with eight different groups of adults. The laboratory colony now being maintained is two generations removed from the parent larval stock. The mosquitoes are thriving under the conditions described in this paper and there is no reason to suspect that they will cease doing so.

The establishment of a laboratory colony of *W. smithii* offers a number of possible avenues of research. The ease with which this mosquito species can be maintained without benefit of any elaborate equipment or rearing room facilities makes it ideal for cultivation in the relatively unspecialized laboratory. A species whose larvae can be reared on rabbit food in finger bowls and whose adults emerge, mate, and oviposit in the confines of a quart jar without benefit of any food but raisins represents almost the ultimate that can be hoped for in mosquito rearing. Only a very few species of mosquitoes have been colonized under these conditions. The consistent egg incubation, pupal, and pre-oviposition periods contribute to a brief life cycle. Unfortunately, there are still problems in mastering the reduction of the relatively long and inconsistent larval stage,

but it is felt that this can be reduced to a consistent 3 to 4 week period with a little more research. The potential laboratory life cycle of one and one-half month duration can then be summarized as follows: egg stage – 3 days; larval stage – 20 to 30 days; pupal stage – 5 to 6 days; adult pre-oviposition period – 4 to 6 days.

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Influence of Food Plant of Host on Attractiveness of the Host to Tachinid Parasites with Notes on Preimaginal Conditioning[1]

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Host-finding and host selection by entomophagous insects are influenced by the plants on which their hosts feed (Milliron, 1940; Simmonds, 1944). Some species of parasites are attracted to certain plants before they receive any stimuli from the hosts (Cushman 1926; Monteith, 1955). Picard and Rabaud (1914) found that many parasitic Hymenoptera attack larvae of species of different families, and even of different orders, provided that they feed on the same species of food plant.

The period and degree of attractiveness to parasites of the food plants of their hosts are important. Thorpe and Caudle (1938) found that when the ichneumonid *Pimpla ruficollis* Grav. is ready to oviposit it is strongly attracted by the odour of the pines on which its host is found. *Drino bohemica* Mesn., a tachinid, is influenced by olfactory and chemotactile stimuli from the food trees of different species of sawflies that it attacks (Monteith, 1955). The order of attractiveness to *D. bohemica* of four species of sawflies is not the same when they are on their food trees as when the larvae are exposed to the parasite in the absence of the food plant.

Host selection by insects may be influenced by preimaginal conditioning. *Conditioning* has been defined (Thorpe, 1951) as the process of acquisition by an animal of the capacity to respond to a given stimulus with the reflex reaction proper to another stimulus when the two stimuli are applied concurrently for a number of times. In relation to the selection of hosts by insects the term conditioning is generally used for the effect that association with a host has had on the sensory system of an insect whose choice of host has been influenced by such association (Monteith, 1955). Thorpe (1956, p. 224) referred to preimaginal conditioning as an effect carried over from the parasitic larval stage

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to the free-living adult stage. Conditioning of an insect to a particular host would be shown by an increased preference for that host. The effect may be on the olfactory or on the chemotactile sensory systems (Monteith, 1955).

This is a report on an investigation into the differences in the attractiveness to tachinid parasites of two species of host when each species has fed on two species of food plants. The role of the food plants of the host in the pre-imaginal conditioning of parasites to new hosts was also investigated.

Material and Methods

Two species of tachinids, *Bessa harveyi* Tns. and *Drino bohemica* Mesn., were tested with larvae of the red-headed pine sawfly, *Neodiprion lecontei* (Fitch), from red pine, *Pinus resinosa* Ait., and from jack pine, *Pinus banksiana* Lamb. The larvae were collected from natural infestations. Although the adult sawflies had deposited their eggs on these trees, their previous history is not known. *N. lecontei* was, however, present during the previous year on the red and jack pine plantations where collections were made.

The responses of the parasites to olfactory and chemotactile stimuli from these larvae were tested in an olfactometer and with random assortments of larvae (Monteith, 1955). The percentages of parasites that selected larvae from each food tree were calculated and the results analyzed by chi-square tests. As in the previous paper, the term *chemotactile* is used to include gustatory, chemical other than olfactory, and tactile stimuli.

The host most frequently attacked by *B. harveyi* in the field is the larch sawfly, *Pristiphora erichsonii* (Htg.). The attractiveness to *B. harveyi* of larch sawfly larvae from tamarack, *Larix laricina* (Du Roi) K. Koch, and from western larch, *Larix occidentalis* Nutt., were tested to determine whether two species of trees of another genus would influence the attractiveness of sawfly larvae that fed on them. These larvae had been restricted to their respective food trees for many generations.

Tests with three successive generations of *D. bohemica* propagated on *N. lecontei* from jack pine were made to determine whether the response to these larvae would increase. Such an increase would indicate the occurrence of pre-imaginal conditioning to the new host. Three generations were tested because in the earlier experiments (1955) conditioning of *D. bohemica* to *N. lecontei* when obtained became evident in the first three generations.

The survival of *D. bohemica* on *N. lecontei* from red pine and from jack pine was tested to determine if a higher percentage of parasites would complete development on one than on the other host. Data on survival would permit consideration of any possible role of the food plant in conditioning the parasite to a host.

The stock of *D. bohemica* used was from a line bred on *N. lecontei* from red pine for 62 generations. A second line was developed by propagating some of this stock for three generations on *N. lecontei* from jack pine. Parasites from the F_{62} generation and from the three generations propagated on larvae from jack pine were tested.

The stock of *B. harveyi* was from a line bred on *N. lecontei* from red pine. Parasites from the F_{22} generation of this line were used in the tests with *N. lecontei* larvae and from the F_{13} and F_{15} generations in tests with *P. erichsonii*.

Sawfly larvae, mostly in the third and fourth instars when collected, were placed in large cages to complete their development on the same species of food tree as that from which they were collected. The characteristics of these

TABLE I

Percentages of eggs deposited by *Drino bohemica* Mesn. from two lines on *Neodiprion lecontei* (Fitch) from red pine and from jack pine during random assortment tests

Parasites	Number of eggs deposited	Percentage of eggs deposited on		P (between larvae)
		N. lecontei from red pine	*N. lecontei* from jack pine	
Reared on *N. lecontei* from red pine				
F_{62}	1680	44.4	55.6	<.005
Reared on *N. lecontei* from jack pine				
F_1	2676	46.6	53.4	<.001
F_2	1574	46.1	53.9	<.003
F_3	686	45.6	54.4	<.02

larvae, the method of holding them in cold storage, and the selection of specimens for use in experiments were described previously (Monteith, 1955).

Results

In the olfactometer *Drino bohemica* reared on *Neodiprion lecontei* larvae from red pine responded in equal numbers to the odours of larvae from red pine and from jack pine; 50 females selected the odour of larvae from each tree. Those parasites reared on larvae from jack pine also showed no significant difference in their responses to odours of larvae from the two trees; 132 flies (48.2 per cent) selected the odour of larvae from red pine and 142 flies (51.8 per cent) that of larvae from jack pine (P>.31). Thus, the food of the host larvae did not affect the attractiveness of the parasite to the larval odours.

D. bohemica from both lines had a definite preference for *N. lecontei* from jack pine during tests with random assortments of larvae (Table I). The difference in the response to larvae from jack pine and from red pine by parasites propagated on larvae from red pine and the F^1, F^2, and F^3, generations of those propagated on larvae from jack pine was highly significant (P<.005, <.001, <.003 and <.02 respectively). This indicated a difference in the attractiveness of the chemotactile stimuli produced by larvae from the two trees.

No increase was found in the degree of preference for *N. lecontei* from jack pine in the three generations of *D. bohemica* bred on these larvae. The number of parasites from each generation that selected them during random assortment tests differed by less than one per cent (between 53.4 and 54.4, Table I). They were selected by 55.6 per cent of the parasites from the line bred on larvae from red pine. A Brandt-Snedecor test (Snedecor, 1946) showed that these differences were not significant (P>.39). There was no evidence of preimaginal conditioning to larvae from jack pine.

B. harveyi preferred *N. lecontei* from jack pine over those from red pine during tests with random assortments of larvae. The parasites selected 513 larvae from red pine and 709 from jack pine (41.9 and 58.2 per cent respectively). The difference is highly significant (P<.005).

B. harveyi preferred larvae of the larch sawfly, *Pristiphora erichsonii*, that had fed on western larch, *Larix occidentalis*, to larvae of the same species that had fed on tamarack, *L. laricina* (Table II). The difference in the selection of these larvae during tests with random assortment of larvae was highly significant (P<.005).

TABLE II

Percentages of eggs deposited by *Bessa harveui* Tns. on *Pristiphora enrichsonii* Htg. from two species of larch during random assortment tests

Generation	Eggs deposited	
	P. erichsonii from western larch	*P. erichsonii* from tamarack
F_{13}, Series I	618	612
II*	263	205
F_{15}, Series I	819	420
II*	450	444
Total	2150**	1681
Percentage response	56.1	43.9

**Neodiprion lecontei* (Fitch) present during the test.
**X^2 (between larvae) = 57.6; $P < .005$.

Survival of *D. bohemica* was higher on *N. lecontei* from jack pine than on those from red pine. Of the parasite larvae from *N. lecontei* on jack pine 49.7 per cent formed puparia as against 42.0 per cent from those on red pine (Table III). The emergence of adult parasites was 34.6 per cent from the larvae fed on jack pine and 30.7 per cent from those fed on red pine. The difference in larval survival and adult emergence were highly significant ($P < .005$ in both cases).

Discussion

The species of food plants on which the sawfly larvae fed definitely influenced the attractiveness of the larvae to *Drino bohemica* and *Bessa harveyi.*

TABLE III

Percentage survival of *Drino bohemica* Mesn. on *Neodiprion lecontei* (Fitch) larvae from red pine and jack pine

Line of parasite	Number of larvae parasitized		Percentage reaching larval maturity on *N. lecontei*		Percentage reaching adult stage on *N. lecontei*	
	From red pine	From jack pine	From red pine	From jack pine	From red pine	From jack pine
Red pine	294	564	41.5	50.4	32.2	34.2
Jack pine F_1	655	956	44.3	53.7	31.7	38.2
F_2	376	813	43.4	48.0	31.6	33.9
F_3	162	174	30.8	33.3	20.9	28.7
	1487	2507	42.0*	49.7	30.7**	34.6

*X^2 (between larval survival on different hosts) = 21.8; $P < .005$.
**X^2 (between adult emergence from different hosts) = 8.1; $P < .005$.

The effect was determined by the chemotactile, rather than the olfactory stimuli produced by the larvae. Monteith (1955) found that olfactory and chemotactile stimuli produced by the food plants of the hosts influenced host-finding by *D. bohemica*. It is now evident that the food plant also influences host selection by changing the attractiveness of chemotactile stimuli produced by the host.

Sawfly larvae apparently have two sets of characteristics that influence tachinid parasites searching for and selecting them. Each set produces different stimuli. Larvae have certain properties because they are of a particular species. They have additional characteristics because they have fed on a particular species of food plant.

Survival of *D. bohemica* on *Neodiprion lecontei* from jack pine was higher than on those from red pine. This did not, however, cause the parasites bred on larvae from jack pine to have an increased preference for these larvae.

There was no evidence of preimaginal conditioning to larvae that fed on jack pine. The absence of conditioning to larvae that were different only because they fed on a certain food tree is similar to the lack of conditioning in *D. bohemica* to stimuli from red pine trees by parasites bred on *N. lecontei* from red pine (Monteith, 1955). The food plants of the host did not in either case influence development of preimaginal conditioning.

Summary

The food plants of the sawfly *Neodiprion lecontei* (Fitch) influenced the attractiveness of the larvae to the tachinid parasites *Drino bohemica* Mesn. and *Bessa harveyi* Tns. The parasites preferred *N. lecontei* fed on jack pine over those fed on red pine when the selection was in response to chemotactile stimuli but showed no preference for the odours of these larvae. Similarly *B. harveyi* preferred *P. erichsonii* fed on western larch to those fed on tamarack. These sawfly larvae have two sets of characteristics that influence host selection by the tachinid parasites: those of the species and those acquired from feeding on a particular species of food tree. Survival of *D. bohemica* was higher on larvae from jack pine but no preimaginal conditioning to these larvae occurred in the parasites propagated on them.

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Observations on the Reproductive Potential of *Melanoplus bilituratus* (Wlk.)[1] (Orthoptera : Acrididae) Reared on Different Food Plants in the Laboratory[2]

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The fecundity of the migratory grasshopper, *Melanoplus bilituratus* (Wlk.), when reared under a variety of conditions, has been reported by a number of authors. In the laboratory, Barnes (1955), rearing cultures of the subspecies found in Arizona on five separate foods, obtained an average production of 8.8 egg-pods per female from those fed the most favourable diet; Parker (1930) reported an average production of 8.8 egg-pods per female from Montana specimens reared on a mixed diet; one of these females laid 15 egg-pods. Under field conditions, Pfadt (1949) in Wyoming and Smith *et al.* (1952) in Manitoba reared this species on a variety of food plants and reported that the greatest numbers of egg-pods per female resulting from use of the most favourable food plants were 9.8 and about 6 egg-pods, respectively.

The rating tables for grasshopper surveys published by Shotwell (1935), and most rating tables subsequently adopted, show an expectation of 4.5 egg-pods per female.

This report on recent work in which *M. bilituratus* was reared on a variety of food plants in the laboratory at Saskatoon suggests that its reproductive potential is considerably higher than that shown by previous authors.

Methods

The grasshoppers were reared in cages similar to those described by Hunter-Jones (1956). The inside measurements were approximately 14 inches square by 10 inches high. Heat was supplied by incandescent bulbs mounted in the rear of the cage: one 25-watt bulb above, and one 15-watt bulb below the false floor. The lights remained on in the cages for 8½ hours each day, during which time the temperature at floor level varied from 86°F. at the front of the cage to 105°F. at the rear, directly between the two lights. At night when the lights were out the temperature varied from 70° to 75°F. Relative humidity in the cages varied from 15 to 30 per cent.

Five non-replicated oviposition experiments were carried out at different times of the year with a number of different food plants; each was continued until all females had died. The number of females per cage varied from 5 to 38; approximately half as many males as females were placed in each cage. The adults were caged for oviposition when still sexually immature.

All of the grasshoppers were from a stock originating from one field near Delisle, Sask. They were either collected from the field in the first instar or were hatched from eggs incubated in the laboratory.

Food material consisted of imported head lettuce, wheat bran, alfalfa meal mixture (Smith 1952) and plants grown locally out of doors such as bromegrass, *Bromus inermis* Leyss.; Thatcher wheat, *Triticum vulgare* Host; flixweed, *Descurainia sophia* (L.) Webb; Russian pigweed, *Axyris amaranthoides* L.; dandelion, *Taraxacum officinale* Web.; and wild mustard, *Brassica kaber* (DC.) L. C. Wheeler var. *pinnatifida* (Stokes) L. C. Wheeler. When fed to the grasshoppers most of the plants were partially submerged in water to maintain suc-

[1] *M. mexicanus* of authors in part (Gurney and Brooks, in press).
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TABLE I

Fecundity of females of *M. bilituratus* reared on various foods in the laboratory

Food	Date test begun	No. of females	No. of eggs per pod	Days lived per female after maturation	No. of pods per female	
					Average	Maximum
Lettuce, bran, alfalfa meal	Dec. 9, 1955	5	23.5	66	21.6	34.6
Lettuce, bran, alfalfa meal	Apr. 22, 1956	5	–	56	17.8	31.3
Lettuce		5	–	63	20.0	26.6
Lettuce, bran		5	–	61	22.0	28.5
Lettuce, bran	May 7, 1956	23	20.2	62	18.7	26.5
Lettuce, bran	May 25, 1956	38	20.9	70	21.6	24.7
Bromegrass	July 25, 1956*	15	19.5	48	9.0	12.7
Wheat		15	20.4	53	11.9	16.9
Flixweed		15	19.6	45	12.7	20.9
Russian pigweed		15	18.3	60	13.6	19.2
Lettuce		15	19.3	57	14.4	23.3
Dandelion		15	19.5	55	17.0	27.3
Mustard		15	21.0	66	20.5	28.8
Wheat and flixweed		15	20.2	60	23.1	43.2
Wheat and mustard		15	22.7	69	25.5	35.0

*Grasshoppers collected from field in first instar; the remainder hatched in the laboratory.

culence. The same diet was used throughout the lifespan of the grasshoppers except wheat, which was replaced by fall rye, *Secale cereale* L., in the latter part of the adult stage.

Egg-pods were removed and counted twice weekly and female mortality was recorded at the same time. The average fecundity was calculated by dividing the total number of egg-pods by the number of females initially present. The maximum fecundity was calculated by dividing the number of pods laid during each interval between removal of the eggs from the cages by the number of females living during this interval, and summing the averages computed for the various intervals.

Results and Discussion

Table 1 indicates the consistently high reproductive capacity of *M. bilituratus* when reared on the different foods; only on bromegrass was the average number of egg-pods per female less than ten. The combinations of wheat with flixweed and with wild mustard resulted in the highest fecundity; the two graminaceous plants, wheat and bromegrass, were the least favourable. It is perhaps significant that two of the less favourable food plants, wheat and flixweed, when combined in a single diet became one of the best, in so far as fecundity is concerned.

Seven of the 15 foods resulted in an average production per female of 20 or more egg-pods. For four foods the maximum calculated production per female was 30 or more egg-pods, and the highest individual production was calculated at 43.2 egg-pods; at 20.2 eggs per pod this would make a total of 873 eggs. The record acridid egg production, as reported by Antoniou and Hunter-Jones (1956) for *Eyprepocnemis capitata* Miller, is 1030 eggs per female;

however, recent work by the author shows that *Melanoplus bivittatus* (Say) is capable of even greater egg production.

On the wheat-flixweed combination, where the highest rate of oviposition occurred, each female averaged one egg-pod every 2.6 days.

After maturation females lived an average of 45 to 70 days.

The fecundity shown by these grasshoppers was about three times as high as that reported by Parker (1930), who reared his grasshoppers on a mixed diet of the foliage of wheat, corn, wandering Jew, and dried alfalfa at room temperatures (69.8° to 86.6° F.). The lower rearing temperatures used by Parker may be suspected of partial responsibility for the lower fecundity; however, he found little difference in the numbers of egg-pods laid at constant temperatures of 99°, 90° and 80°F. Barnes (1955) obtained the highest egg production from grasshoppers fed on a mixed diet of alfalfa and several weeds at variable temperatures (maxima 85° to 90°F. and minima 63° to 64°F.).

The considerably higher fecundity obtained in the present trials cannot be explained at present. It may be due to differences in rearing techniques or to the higher reproductive potential of the local population. In any event, such a high reproductive capacity may well help to explain the rapid population increases that occur during a grasshopper outbreak.

Summary

The reproductive capacity of *M. bilituratus* was shown to be considerably higher than previously reported. An average of more than 20 egg-pods per female was produced when the grasshoppers were reared on lettuce; lettuce and bran; lettuce, bran, and alfalfa meal; wheat and mustard; wheat and flixweed; or mustard. The highest average individual production, which occurred on the wheat-flixweed combination, was calculated at 43.2 egg-pods, or 832 eggs. Combinations of wheat with flixweed and with mustard resulted in the highest average fecundity (23 to 25 egg-pods per female), whereas the graminaceous plants wheat and bromegrass, when fed alone, resulted in the lowest (9 to 12 egg-pods per female). The number of adults per cage, varying from 7 to 58, appeared to have no effect on the number of egg-pods laid.

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Two New Species of Fleas from Utah, with Notes on the Genus *Ornithophaga* Mikulin (Siphonaptera)[1]

By G. P. Holland[2] and G. Loshbaugh, Jr.[3]

The two new species of fleas described in this paper are of unusual interest. The first belongs to the well-known genus *Catallagia* Rothschild (Hystrichopsyllidae: Neopsyllinae), but is notable for the extreme modification of the male genitalia, a condition not reflected in the female; the second, a bird flea, belongs to *Ornithophaga* Mikulin (Leptopsyllidae: Amphipsyllinae), a remarkable genus recently described from the U.S.S.R. on the basis of one female specimen.

The specimens on which the descriptions are based were obtained by the junior author when he was associated as an enlisted man in the United States Army with the University of Utah, Ecological Research Project at Dugway, Tooele County, Utah, under contract with the Army Chemical Corps. Recognized as new, they were submitted to the senior author, who worked out their taxonomic positions and prepared tentative descriptions and illustrations. Later, discussions of these and other species incorporated into the Master's dissertation of the junior author at the University of California.

As *Ornithophaga* Mikulin was described in a publication that may not be conveniently available to most North American students of fleas, and as male specimens were not available for consideration when it was erected, the genus is redescribed here, with some supplementary notes on adaptive evolution in bird fleas.

Catallagia neweyi new species

Resembling *Catallagia charlottensis* (Baker), the type of the genus, and several other species in general facies, but differing from all previously known species in the remarkable development of some structures of the male genitalia, especially the movable process of the claspers and the distal arm of sternum IX. As in *C. jellisoni* Holland, chaetotaxy of the movable process suggesting close affinity with the genus *Epitedia* Jordan.

Male

Ocular setae four, in a nearly even row, as in *C. charlottensis;* about six frontal setae (Fig. 1). Postantennal region with two oblique rows of setae in addition to a submarginal one. A small fronto-clypeal tubercle present. Eye as in other species of the genus. Labial palpus five-segmented, and approximately two-thirds as long as fore coxa. Second antennal segment with short setae.

Structure and chaetotaxy of thorax not differing significantly from those of *C. charlottensis* and some other species. Pronotal comb of about 14 broad spines. Three pseudosetae on each side, under the collar of the mesonotum; metanotum lacking pseudosetae.

Hind coxae with a row of spiniform setae, and abdominal sternum II with a lateral "striarium". Tarsal segments V of fore- and mid-legs with four lateral pairs of plantar bristles and a basal submedian pair; tarsal segment V of hind leg with four lateral pairs.

Apical spinelets of abdominal terga as follows: I, 1 spine per side; II, 2 spines (or 1); III, 1 spine; IV, 1 spine (or 0). Abdominal terga II-VII each with two rows of setae, the anterior row of about six short setae and the

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posterior row of about seven long setae, those of the posterior row alternating with fine intercalary hairs. Spiracles of abdomen small, not enlarged.

Typical sternum with anterior row of one or two fine setae, and posterior row of about three well-developed setae.

Antesensilial setae three, of which the upper is about one-half, and the lower slightly more than one-half, as long as the middle one. Sternum VIII broad, bearing ventrolaterally about three strong, and five weak, setae; caudal margin produced into a long flap-like process not unlike that of *C. charlottensis*.

Clasper broad and unusually deep (Fig. 2), with narrow, straight manubrium. Dorsoposterior apex (fixed process) of clasper rounded, somewhat concave on the caudal margin, and fringed with about 20 short setae; an acetabular seta set low down. Movable process long and narrow, its apex exceeding the fixed process; differing from all other species in having the posterior margin distinctly concave, but in this respect resembling some species of *Epitedia*. Movable process with heavily sclerotized articulation, and with anterior margin above the articulation projecting like a tooth (Fig. 3). Posterior margin and lower lateral surface of movable process vested in thin setae, as illustrated. Three heavy, almost spiniform setae submarginally on the lower mesal surface, the upper one directed caudad, the middle one strongly curved or twisted medially, and the lower and thickest seta straight and directed anteriorly. Sternum IX very distinctive, with proximal arm narrowed medially and expanded apically with the posterior angle extending in a distinct, pointed, lobe (Fig. 2); distal arm generally narrow, but terminating apically in a remarkable, claw-like structure. The apex of the sclerite (Fig. 4) demarcated by a narrow constriction, and bearing three heavy and deeply pigmented spiniforms on its posteroventral surface. Two of the spiniforms tooth-like and of approximately equal size; the third more than twice as large, and bent at a right angle at its base. On sternum IX, a thin seta dorsally, above the constriction, and about six thin setae mesally and another six ventrally.

Female

Details of chaetotaxy essentially similar to those of the male.

Second antennal segment with marginal setae about half as long as the club.

Anal stylet about four times as long as broad; a long apical seta with a minute hair at its base. Stigma cavity of tergum VIII relatively narrow. Sternum VII similar to that of *C. decipiens* Rothschild, with broadly rounded lobe and sinus but with the lobe slightly more angular ventrally and the sinus deeper than in that species (Fig. 5). Sternum VII with about six long setae and seven to ten light ones. Spermatheca as in all species, the hilla projecting deeply into the lumen of the peanut-shaped bulga.

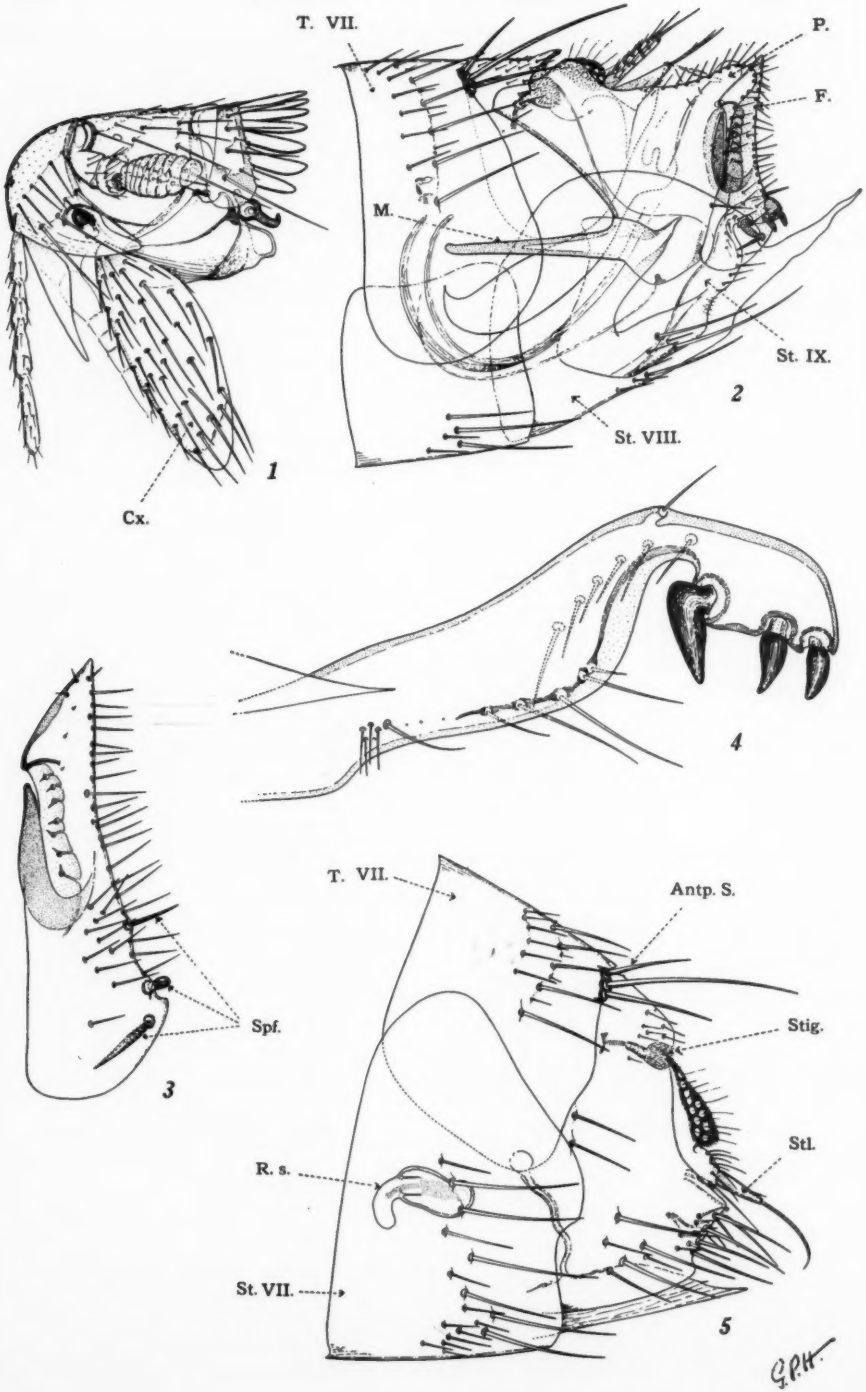
Size (mounted specimens): ♂, average 2.4 mm. (2.3-2.5); ♀, average 2.6 mm.

Holotype.—♂, ten miles east of Gold Hill, Tooele County, Utah, 7.X.53, collected from *Peromyscus maniculatus sonoriensis* (LeConte) by E. A. Shippee.

Allotype.—♀, same data.

Paratypes.—5 ♂ ♂ and 1 ♀, as follows: same data as holotype and allotype, 3 ♂ ♂, 1 ♀; northeast side of Granite Park, Tooele County, Utah, 19.XI.52, collected from *Peromyscus crinitus pergracilis* Goldman by J. P. Newey, 2 ♂ ♂.

Holotype and allotype in the United States National Museum, Washington, D.C. Paratypes in the Canadian National Collection of Insects, Ottawa; the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Stig.
Stl.
R. s.
St. VII.
G.P.H.

British Museum (Natural History) Zoological Museum, Tring, Herts., England; and the Rocky Mountain Laboratory, Hamilton, Montana.

The species is named after J. Paul Newey, a devoted mammalogist and collector of ectoparasites.

Comments

The mesal spiniforms of the movable process of the claspers, most conspicuous in *Catallagia neweyi,* are prominent in *C. jellisoni* and two Russian species. Modified setae in this position are readily discernible, too, in *Epitedia faceta* (Rothschild) and examination revealed that all described species of *Catallagia* and *Epitedia* except the aberrant species *C. borealis* Ewing and *E. scapani* (Wagner) have two or three setae, usually not, or not much, thicker than the marginal setae of the movable process, inserted on the mesal surface near the posterior angle of that structure and presumably homologous with the spiniforms that are so conspicuous in *C. neweyi.* Only in *C. neweyi,* however, is one of the setae directed cephalad, and even more remarkably, one of them twisted like a corkscrew. Twisted setae such as these are extremely rare in Siphonaptera; the only similar case known to the authors occurs in species of *Strepsylla* Traub (also Neopsyllinae), in which there are twisted spiniform setae on either side of sternum IX.

In all known species of *Catallagia* and *Epitedia* the distal arm of sternum IX of the male terminates in one or more spiniform setae, the usual number being four or five, in a marginal row, with sometimes another series submarginally. *Catallagia borealis* and *C. wymani* (Fox) have only one apical spiniform, but members of the *charlottensis* group (e.g., Holland, 1951), to which *C. neweyi* belongs, in general have three or four such spiniforms. In all species but *C. neweyi,* the apex of the sternum is not constricted, and the spiniforms are small and not strongly modified. In *C. neweyi,* however, the apex of sternum IX is set off from the rest of the sclerite by a strong ventral constriction, and is armed with three large spiniforms of which one is especially large and strongly modified in shape.

In the Ceratophyllinae, sternum IX and the claspers are used to seize the female abdomen in copulation and facilitate entry of the penis rods (e.g., Holland, 1955), and it is presumed that these structures perform similar functions in *Catallagia* and related genera. However, in the apparent absence of unusual sexual modifications in the female of *C. neweyi,* it is difficult to speculate on the survival advantage of the remarkable genitalic structures of the male.

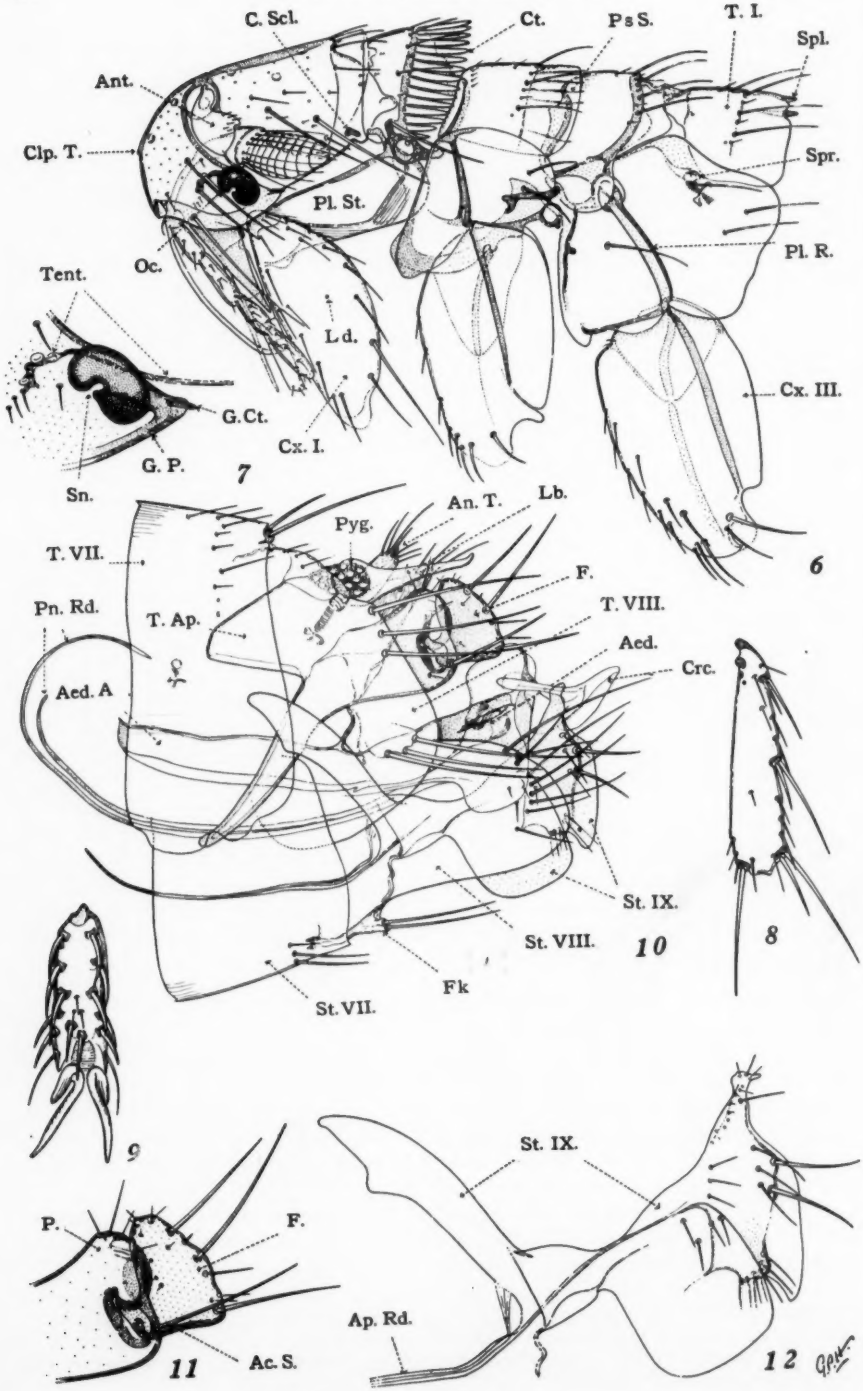
Ornithophaga Mikulin

Ornithophaga Mikulin 1956, pp. 79-82.

Head rounded as in a ceratophyllid (Fig. 6); with small frontoclypeal tubercle. Pre- and post-antennal rows of setae greatly reduced. Anterior tentorial arch conspicuous in front of eye. Eye large, heavily pigmented, especially in lower portion, and with a strong ventral sinus (Fig. 7). Genal process bearing a single ctenidial spine. Second antennal segment with long marginal setae, exceeding the club in both sexes.

Pronotum with comb. Sclerites of thorax sparsely vested in setae. Mesonotum bearing pseudosetae under the collar, but metanotum lacking apical spinelets. Metathorax with pleural arch.

Figs. 1-5. *Catallagia neweyi* n. sp. 1, Head and prothorax of male. 2, Terminal abdominal segments and genitalia of male. 3, Enlarged detail of movable process of clasper of male. 4, Enlarged detail of distal arm of sternum IX of male. 5, Terminal abdominal segments and genitalia of female.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Ap. Rd.
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11
12

Vestiture of coxae and legs much reduced. Tarsal segment V with five pairs of plantar bristles of which the third pair are sub-mesal, the remaining pairs being marginal (Fig. 9).

Abdominal terga with reduced vestiture; some apical spinelets present.

Male with tergum VIII virtually unmodified; sternum VIII expanded posteriorly, and fringed with setae. Claspers simple. Distal arm of sternum IX with complex ventral lobes. An intersegmental fork arising ventrally in the membrane lying between sterna VIII and IX.

Female with spermatheca of simple form. Bursa copulatrix curved and well sclerotized.

Type of the Genus.—*Ornithophaga anomala* Mikulin, 1956, described from one female, collected from a "trydactylous woodpecker" (*Picoides tridactylus* (Linn.), a Holarctic species) collected in May, 1953, in the Kumyrch' Ravine, Ketmen' Range, Alma-Atinska District, Kazakhstan, U.S.S.R.

***Ornithophaga nearctica* new species**

Known from one male only, but presumed to differ specifically from *O. anomala*, partly on geographical grounds and partly because *O. anomala* is stated (Mikulin, in litt.) to have two rows of setae on the metanotum rather than one.

Male

Head *Ceratophyllus*-shaped, with setae, especially those of the ocular region, arranged as ordinarily found in Certatophyllidae but not in Leptopsyllidae. Ocular setae three, in a row, the uppermost not set well forward of the eye on the margin of the antennal fossa (Fig. 6). Antenna long, set high on the head, which has an interantennal suture. Marginal setae of antennal segment II very long, exceeding the apex of the club. Eye large, well pigmented, almost divided ventrally by a deep sinus. Genal process (Fig. 7) bearing a single, short spine. Labial palpus five-segmented and approximately two-thirds as long as fore coxa.

Pronotal comb of about 30 slender, pigmented spines. Mesonotum with a single row of setae and a few scattered hairs; four pseudosetae on each side. Metanotum with a single row of four or five setae on each side, and lacking apical spinelets on the flange. Other details of structure and chaetotaxy of the thorax as shown (Fig. 6). Forecoxa with submarginal setae only, a small pit on the outer surface being a lucodisk and not a setal socket. Mid- and hind-coxae narrow, and legs with vestiture reduced, probably indicating a nest-existence. Hind tibia with only two major pairs of bristles in notches, and an apical pair (Fig. 8). Hind coxae without a patch of spiniforms. Tarsal segment V with five pairs of well-developed plantar bristles of which the third pair are sub-mesal rather than marginal (Fig. 9).

Setae of abdominal terga II-VII reduced in number and strength there being only one row of thin, weak setae posteriorly, and the anterior row represented only by a single seta. Apical spinelets as follows: I, 2; II, 2; III, 2; IV, 1 (or 2); V, 0. Tergum VII with two antesensilial setae, the lower one twice as long as the upper one. Sterna II-VII each with a few weak, ventral setae.

Tergum and sternum VIII of normal leptopsyllid form, with several long marginal and submarginal setae that serve to protect the external genitalia (Fig. 10). At the base of sternum VIII an intersegmental fork, bearing two

Figs. 6-12. *Ornithophaga nearctica* n. sp. (holotype male). 6, Head and thorax. 7, Enlarged detail of eye, tentorial arch, and genal process. 8, Hind tibia. 9, Tarsus V of hind leg. 10, Terminal abdominal segments and genitalia. 11, Enlarged detail of processes of clasper. 12, Enlarged detail of sternum IX.

strong apical setae. Caudad of the sensilium, tergum X produced in a long lobe on either side, enclosing the proctiger.

Clasper simple, with single acetabular seta at base of the movable process. Fixed process rounded, with three apical setae. Movable process (Fig. 11) subtriangular, slightly exceeding fixed process, and lacking spiniforms. Three long and several short setae situated along the margin as shown.

Sternum IX (Fig. 12) with simple proximal arm and complex distal arm bearing two pairs of deep lobes ventrally and a small apical lobe. A number of long and short setae disposed as illustrated. Penis rods and apodemal rod of sternum IX short (Fig. 10). Aedeagus with conspicuous dorsal and lateral lobes and a large, articulated crochet.

Size (mounted specimen): 2.6 mm.

Holotype.— ♂, West Hickman Canyon, Stansbury Mountains, Tooele County, Utah, 17.XII.53, collected from *Dendrocopos pubescens leucurus* (Hartlaub) by R. D. Porter; in the United States National Museum, Washington, D.C.

Comments

Mikulin (1956), in establishing *Ornithophaga*, made no firm decision on its taxonomic position, comparing it with *Mesopsylla* Dampf (Leptopsyllidae) on the one hand and with the Ceratophyllidae on the other. He inclined towards the ceratophyllid interpretation but rightly withheld a final decision pending discovery of male specimens.

The present authors would assign *Ornithophaga* to the Leptopsyllidae, subfamily Amphipsyllinae (*sensu* Hopkins and Traub, 1955) but note that it lacks any obvious affinities with any other described genus in the family and that it bears a strong superficial resemblance (especially in the female) to some Ceratophyllidae; this resemblance is evidently a case of parallelism resulting from the transfer from a mammalian to an avian host. A number of genera of Ceratophyllidae are principally associated with birds, and it is to this group that the similarities are especially marked. The picture is further complicated by a general reduction in vestiture; this probably indicates that *Ornithophaga* spp. are principally nest fleas (presumably woodpecker nests), which would explain their rarity in collections.

Principal leptopsyllid characters are the conspicuous anterior tentorial arch, the unreduced sternum VIII of the male, the absence of the gland of Wagner, and the presence of an intersegmental fork. Other suggestive characters are the slight indication of an interantennal suture in the male (not in the female); the presence of a genal comb; the ventrally divided eye, which is somewhat similar to that of some species of *Ophthalmopsylla* Wagner and Ioff; and the form of the spermatheca and bursa copulatrix (as illustrated by Mikulin, 1956), which are reminiscent of species of *Amphipsylla* Wagner.

"Ceratophylline" characters include the general profile and vestiture of the head, especially the ocular setae, the long setae on antennal segment II, and the arrangement of the plantar bristles on the tarsi.

A remarkable fact that has been noted numerous times is that bird fleas belonging to the Ceratophylloidea (as opposed to the Pulicoidea) invariably have more spines in the pronotal comb than do their nearest relatives on mammals. As indicated by Jordan (1933) the critical number appears to be about 12 (spines per side); fleas with fewer than 12 spines live on mammals, whereas virtually all that have more than 12 infest birds.

Of the Ceratophyllidae, all species of *Dasypsyllus* Baker and *Mioctenopsylla*

Rothschild (though here the spines are much shortened) and nearly all species of *Ceratophyllus* Curtis (*s. str.*) are bird fleas, and have this feature. *Orneacus* Jordan is separable from *Paracallopsylla* Ioff only for the species, on birds, that have a large number of pronotal spines. Of the predominantly Australasian family Pygiopsyllidae, only the bird-infesting genus *Hoogstraalia* Traub, and one species of *Stivalius* Jordan that lives on birds instead of rodents or marsupials, have a large number of pronotal spines. Of the Leptopsyllidae, *Frontopsylla* Wagner and Ioff is predominantly a genus of mammal fleas, but *Orfrontia* Ioff is recognized as a subgenus containing the many-spined species that live on birds. *Ornithophaga* conforms to the pattern, though close relatives on mammals are not known for comparison. No one, so far, has advanced a reasonable explanation as to why it should be advantageous for a bird flea to have a large number of slender spines on the pronotum rather than a smaller number of thick ones.

Another character of *Ornithophaga* common in other bird fleas is the reduced posterior margin (with loss of apical spiniforms) of the metanotum.

A final feature of *Ornithophaga*, and one that is not otherwise known in the Leptopsyllidae but finds an exact parallel in ceratophyllid bird fleas of the genus *Dasypsyllus*, is the arrangement of the plantar bristles on the terminal segments of the tarsi. In both cases, instead of having five pairs all situated laterally as occurs in most fleas, the third pair are shifted towards the mid-line of the sole. If this is a case of adaptive evolution it is surely a remarkable one, and the survival advantage of such a character is not apparent to the authors.

Summary

Two new species of fleas are described from Utah. *Catallagia neweyi*, from white-footed mice, differs from all previously known species in the extensive development of spiniform setae on the movable process of the clasper and sternum IX of the male. The genus *Ornithophaga* Mikulin is redescribed and assigned to the Leptopsyllidae, subfamily Amphipsyllinae, principally on the development of the tentorial arch, the eye, and modified abdominal segments of the male. *O. nearctica* is described from a downy woodpecker. *Ornithophaga* spp., like other bird fleas of the Ceratophylloidea, have a larger number of spines on the pronotum than do mammal fleas of the same superfamily.

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Common Names of Insects

"And out of the ground the Lord God formed every beast of the field, and every fowl of the air: and brought them unto Adam to see what he would call them: and whatsoever Adam called every living creature, that was the name thereof." — Genesis 2:19.

There is such a great number of species of insects that Adam's task, at least in this great class of "beasts" is by no means finished. There are names of insects in every language of the world. There are also "scientific" Latin names governed by an agreed set of rules and are therefore the most accurate. They are truly international, but have meaning only for the entomologist and a few others. For this reason, the so-called "common" names, are used by the public, who are free to coin new ones whenever they like.

To communicate with those outside their profession, entomologists must use common names. Unfortunately common names present difficulties: their use is local; they vary in meaning from place to place; they are inexact; and are not always apt.

The need for common names and some control to overcome their disadvantages has long been recognized. Two lists of carefully selected common names have been offered as attempts to standardize usage. One, a list of English names published by the Entomological Society of America in 1955, is the decendant through four revisions of a list published in 1908 by the American Association of Economic Entomologists; the other, a list of French names published in 1952 by the Quebec Society for the Protection of Plants, traces its ancestry to a list published by Abbé Provancher in 1871. Both of these lists are widely used in North America in their respective language areas.

Committee on Common Names of Insects

The Entomological Society of Canada set up a Committee on Common Names of Insects in 1952. Later each of the regional societies (The Entomological Societies of British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, and the Acadian Entomological Society) set up a common names committee. The national committee is composed of the chairmen of the regional committees and two additional members, one of whom must be a taxonomist. It recognizes the English names approved by the Entomological Society of America and the French names published by the Quebec Society for the Protection of Plants.

The objects of this committee are to control the establishment of common names and to encourage the members of the regional societies and of the Entomological Society of Canada to propose names where they are needed. By controlling the establishment of common names is meant the examination of proposals to determine the fitness of the proposed name and to determine if a common name is needed. The regional committees periodically review the insects of importance in their regions and propose, or ask members to propose names when they are needed.

When does an insect need a common name?

An insect may need a common name because it is economically important, of striking appearance, or very abundant. Other reasons are possible. There are insects that are economically important but do not need names: for example, a gall midge may cause serious damage, but it is the damage (gall) that needs the name, not the pest (midge). *Actias luna* (L.) and *Megarhyssa atrata* (Fab.) are each of striking appearance, and most people would agree that the second

is more striking than the first, yet "luna" is a very old common name and *M. atrata* will probably never need one. Abundance is one of the most difficult reasons to evaluate but the best measure of whether an insect is abundant enough to need a name is the frequency with which the public refers to it. In general, an insect needs a common name if the public must refer to it often, or if entomologists must refer to it often in their relations with the public and a group name is not good enough.

How do I propose a common name?

If you wish to propose a name contact any member of your regional Committee on Common Names of Insects. He will give you a proposal form and whatever advice he can. The most important thing about this form is that you must give detailed reasons for your proposed name and tell why it is better than any other names that may have been used. It is up to you, not the committee, to do the research.

Your proposal is considered by three committees, and should be given to the regional committee first. If it is accepted it will be forwarded to the chairman of the national committee who will ask the members of his committee to vote on it. This is not a mechanical procedure because even if your proposal receives (or does not receive) enough votes to pass, the chairman can ask the committee members to reconsider their votes if any of them should find a good reason why your proposal should be rejected (or accepted). Your accepted proposal is sent to the Committee on Common Names of Insects of the Entomological Society of America in a list of proposed additions to the official list. If no objections are received within thirty days, the name is incorporated into the official list.

If your proposal is rejected at any of these three levels it is returned to you through your regional committee with the reasons for its rejection. This, of course, should not end the matter if the insect really needs a common name. If any of these three committees feels the insect does not need a name they will say so and tell you why; if they still feel it needs a name they will offer suggestions and may propose an alternative name for your consideration.

What constitutes a good name?

The Committee on Common Names of Insects of the Entomological Society of America examined this subject very carefully (J. Ec. Ent. 46: 207-11) in an article entitled "An Appeal for a Clearer Understanding of Principles Concerning the Use of Common Names". This article should be read before anyone attempts to propose a name. It would be good if every entomologist in Canada read the article, particularly those who are skeptical about the value of common names. In this article eight rules and recommendations are given to serve as guides:

1. Included species will in most cases inhabit the United States, Canada or their possessions and territories. In special cases other species may be added.
2. The list is intended for those insects and other invertebrates which commonly are of concern to entomologists because of their economic importance, striking appearance, abundant occurrence, or for any other sufficient reason.
3. Where possible, more than three words should be avoided in a common name, but four are permissible if reasons are sufficient.
4. In the case of names having two parts, one of them a group name, it is desirable that a separate word be used for the group name if it is

used in a sense that is systematically correct. Example: "house fly", as contrasted with "dobsonfly".

5. The use of parts of the scientific name in the common name is undesirable unless the words involved are thoroughly established by usage as a common name.
6. Only in special cases should a species have more than one common name.
7. In the case of insects of concern to the entomologist in both the larval and adult stages the name preferably should apply to the most important or best known stage or to the one for which usage has established the better name.
8. In all cases involving the adoption of new common names or changes in those previously established, the fullest consideration should be given to past usage and probable future usage. Members who wish to recommend new names or changes in existing ones should accept the reponsibility of making the necessary investigation. In so far as possible, the considered opinions of entomologists experienced with the insects concerned should be obtained before names are proposed, and all of the available evidence, both for and against, should accompany the proposal when it is submitted to the Committee.

The Use of Common Names

Every entomologist should use accepted names in his dealings with the public. Articles, bulletins, spray calendars, and other forms of extension literature are still being published that use other than accepted names. It is no less important in speaking than in writing. When both entomologists and laymen use one name for each insect a lot of confusion will be avoided, and everybody will gain.

D. C. EIDT
for Committee on Common Names of Insects
Entomological Society of Canada

A New Species of *Plagiognathus* from Alfalfa in Western Canada (Hemiptera : Miridae)[1]

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A species of *Plagiognathus* Fieber damaging alfalfa in Western Canada has been variously reported as *Plagiognathus obscurus* Uhler, *Plagiognathus obscurus fraternus* Uhler, or *Plagiognathus* sp., (Arnason *et al.*, 1948, 1951; Handford and Neilson, 1950, 1951; McMahon *et al.*, 1949, 1950; McMahon 1950 a and b; McDonald *et al.*, 1952-1955).

This species is herein described as *P. medicagus* n. sp.

P. obscurus and *P. fraternus* were originally described by Uhler (1872, 1895) though he had at hand only three specimens, including both sexes, of *fraternus*. Knight (1923, 1941) concluded that *fraternus* was merely a variety of *obscurus*, after finding only three specimens that fitted the original description of *fraternus* in color of scutellum and pronotum in a large amount of material from Colorado and the eastern United States. He determined as of *fraternus* those specimens having the scutellum entirely black, "even though the pronotum might also be black", and as of *obscurus* those with the lateral margins of the scutellum more or less pale. He reported that *obscurus*, *fraternus*, another variety, *albocuneatus* Knight (1923), and intermediates between these varietal forms were found together in the field in Illinois.

A somewhat similar variable population was found in extensive collections from various native plants in Saskatchewan, sorted according to Knight (1923, 1941). However, regardless of host, over 80 per cent of those determined as of *fraternus*[3] were males, and over 90 per cent of those determined as of *obscurus*[3] were females.

In contrast, specimens from alfalfa[4], exclusively of *P. medicagus* n. sp., are very uniform though they fall within the range of variation ascribed by Knight (1923, 1941) to *P. obscurus*. They exhibit very little color variation or sexual dimorphism, and are generally shorter and darker than the variants of *P. obscurus*. They do not fit the original description of *P. obscurus* Uhler (1872) or *P. fraternus* Uhler (1895).

That the difference between *medicagus* n. sp., and *obscurus* are not due to a food factor is indicated by the presence of both species, in nymphal and adult stages, on various native plants. Also, nymphs of *obscurus* collected from these plants and reared on alfalfa developed into adults that retained all the characteristics of that species.

During regular sampling of alfalfa and native plants no differences between the seasonal development of *medicagus* and that of *obscurus* were observed.

The genital claspers of the males of the two species appear identical. The sclerotized rings of the *medicagus* females may vary less than those of *obscurus*, but the range of variation falls within that for the latter species.

The two species may be separated as follows:

Male: costal margin of hemelytron at most slightly curved; pronotum almost

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[3]Identification of several specimens of *obscurus* and *fraternus* corroborated by H. H. Knight, Ames, Iowa, and R. Sailer, United States National Museum, Washington, D.C.

[4]Determined as *Plagiognathus* sp., not *obscurus fraternus*, by R. Sailer, United States National Museum, Washington, D.C.

Figure 1. Left, *Plagiognathus medicagus* n. sp.; right, *Plagiognathus obscurus* var. *fraternus*.

always partly pale, rarely all black, the pale portion occasionally being limited to a brown area along posterior margin; cuneus almost always more than half pale, rarely darker, occasionally entirely pale; anterior margin of dark spot on corium in darker specimens more or less evenly curved (Fig. 1); scutellum usually black, occasionally yellow at lateral margins; length 3.9 - 5.2 mm. Female: costal margin of hemelytron more distinctly curved; pronotum almost always partly pale, rarely entirely black; scutellum usually pale at edges, occasionally dark; abdomen partly yellow; length 3.9 - 4.9 mm. ..... *obscurus* Uhler

Male and Female: costal margin of hemelytron distinctly curved; pronotum black; cuneus less than half pale; anterior margin of dark spot on corium distinctly emarginate (Fig. 1); scutellum always black; abdomen black; length 3.7 - 4.8 mm. ..... *medicagus* n. sp.

***Plagiognathus medicagus* n. sp.**

Male (*holotype*).—Length 4.25 mm., width 1.56 mm.

Head: width 0.77 mm.; width at vertex between eyes 0.38 mm.; length 0.44 mm.; head fuscous to black with a yellow spot between eyes centred along the occipital carina; eyes dull red with pale yellow along the posterior margin; anterior portion of ventral margin of buccula narrowly yellow; antennal socket pale within; tylus black, ventral margin narrowly yellow. Rostrum 1.43 mm. long, reaching hind coxa; fuscous to black, with apex of first segment yellow, and centre of second segment, apex of third, and base of fourth pale. First antennal segment 0.37 mm. long, black, the apex narrowly yellow; second segment 1.18 mm. long, black to fuscous, the base narrowly yellow; third segment 0.66 mm. long, brown, the base darker; fourth segment 0.42 mm. long, brown.

Pronotum: length 0.57 mm.; anterior width 0.65 mm.; width at base 1.19 mm.; black to dark brown; calli slightly elevated, oval; pectus and pleural flaps black; scutellum black; mesoscutellum black, narrowly pale on the lateral edges.

Legs: coxae yellow, fuscous to black at bases; each femur dark yellow to fuscous with a black line on posterodorsal surface and on posteroventral surface, and with two loose rows of black dots on both anterior and posterior surfaces. Hind tibia 2.08 mm. long. All tibiae yellow, each with a black spot at base and a posterodorsal and an anterodorsal row of black spines, each spine with a black spot at base; tarsi fuscous to black, slightly paler on middle portions.

Hemelytra: clavus mostly black, pale at extreme posterior tip and narrowly pale along anterior half of claval suture; corium mostly black with basal one-

third, a small spot on posterolateral margin, and a narrow line along anal ridge, pale; cuneus 0.70 mm. long, mostly fuscous with basal one-fourth and extreme apex pale; membrane dark, veins pale.

Abdomen: black.

Female (*allotype*).—Similar to male in color and form; length 4.20 mm., width across hemelytra 1.69 mm.

Variation.—This is an extremely uniform species in both form and color. The females are generally slightly wider across the hemelytra than the males. The males vary in length from 3.73 mm. to 4.75 mm. and in width across the hemelytra from 1.34 mm. to 1.69 mm.; the females vary in length from 3.78 mm. to 4.73 mm. and in width from 1.43 mm. to 1.89 mm. The length of the cuneus varies from 0.52 mm. to 0.78 mm. and the length of the hind tibia from 1.82 mm. to 2.21 mm. The dark color in some specimens is jet black and in others brownish-black; some are densely clothed with pale hairs but the hairs are evidently very easily lost so that most specimens are without hair or only sparsely clothed with hairs. In most specimens the last two antennal segments are considerably paler than the first two, but in some all the segments are uniformly black. The bucculae are usually narrowly pale along the ventral margins but occasionally they are wholly black. The rostrum usually has extensive pale areas but sometimes it is wholly black or dark brown. The mesoscutellum varies from black with very narrow pale areas on the lateral margins to black with wide pale areas on the lateral margins. The pale areas of the hemelytra are usually colorless or white but sometimes they are tinged with yellow. The cuneus varies from approximately one-quarter pale to approximately one-half pale; it is rarely more extensively pale.

Holotype.—Male, Garrick, Sask., July 26, 1956, collected on *Medicago sativa* L. (J. C. Arrand), No. 6550 in the Canadian National Collection, Ottawa.

Allotype.—Female, Garrick, Sask., July 26, 1956, collected on *Medicago sativa* L. (J. C. Arrand).

Paratypes.—50 males, 50 females, Garrick, Sask., July 26, 1956, collected on *Medicago sativa* L. (J. C. Arrand).

Known Distribution.—Specimens of *Plagiognathus medicagus* were found in various collections from the following points:—BRITISH COLUMBIA: Victoria, Hazelton, Goldstream (miscellaneous collections); Vernon, Quesnel, Stump Lake (on *Medicago sativa* L., C. L. Neilson); Farrell Creek, Bear Flat, Fort St. John, Doe River, and Rolla (on *Medicago sativa* L., miscellaneous collections). ALBERTA: Nordegg (miscellaneous plants, J. McDunnough), determined by Knight (1925) as *P. obscurus fraternus;* Canmore (miscellaneous plants, L. A. Konotopetz); Sangudo, Crowsnest Pass, Lethbridge (miscellaneous plants, J. H. Pepper and R. W. Salt); Elkwater (on *Lupinus argenteus* Pursh, A. R. Brooks and L. A. Konotopetz); Wapiti, Dimsdale, Grovedale, Big Smoky Bridge, and Debolt (on *Medicago sativa* L., miscellaneous collections). SASKATCHEWAN: Loon Lake, Goodsoil, Meadow Lake, Dorintoch, St. Cyr Lake (on *Medicago sativa* L., J. C. Arrand); Waskesiu (miscellaneous plants, A. R. Brooks); Smeaton (on *Medicago sativa* L., J. C. Arrand); Garrick, Love, Torch River, White Fox, Nipawin, Carrot River, Ravendale (on *Medicago sativa* L., *Artemisia biennis* Willd., *Urtica gracilis* Ait., *Chenopodium album* L., *Epilobium angustifolium* L., *Solidago canadensis* L., *Senecio eremophilus* Richards (after Rydberg), *Potentilla fruticosa L., Rubus idaeus* var. *strigosus* (Michx.) Maxim., J. C. Arrand); Elbow (miscellaneous plants, A. R. Brooks and L. A. Kelton; MANITOBA: Wanless, Mafeking (on *Medicago media* Pers., H. McMahon); and Aweme (mis-

cellaneous plants, N. Criddle), Winnipeg (miscellaneous plants, R. H. Ross). MONTANA: Browning (miscellaneous plants, L. A. Konotopetz).

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Insects and Physiological Research[1]

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In the foreword to the initial issue of the "Journal of Insect Physiology", V. B. Wigglesworth states: "—the key to many of the fundamental problems of physiology may perhaps be found most readily among the insects" (15). This expresses a viewpoint that he and others have enunciated on previous occasions (10, 14). It is well substantiated by a consideration of the general and particular characteristics of insects and the contributions that have been made to general physiology through their study.

What advantages for physiological investigation have these small, multicellular, relatively short-lived and fecund organisms? The short life cycle and rather high reproductive capacity of most insect species makes it possible to bring many studies to fruition relatively quickly. In addition, these two attributes facilitate breeding for genetic homogeneity. Uniformity of the experimental population is a desirable characteristic and is of particular value when the material is well known genetically as is the case with *Drosophila melanogaster*. No animal has been as intensively studied by geneticists as *Drosophila*. Success in rearing this insect in aseptic-culture, on a chemically defined medium, has added to its importance as an experimental organism of standardized uniformity.

The small size of most insects may be disadvantageous for some physiological studies due to the limitations imposed by the lack of suitable microtechniques of measurement and manipulation. In recent years, however, there have been many advances in this respect, especially in the fields of ultramicrochemical analysis and microscopy. Frequently, ease of handling, limited space requirements, low cost of maintenance, and possibilities for replication are significant advantages more than adequately compensating for any disadvantages of small size.

Despite their small size some insects possess biological structures of comparatively large proportions. Most notable of these structures are undoubtedly the "salivary gland" chromosomes of some dipterous larvae. These structures, which apparently are composed of many reduplicated chromonemata in longitudinal association, have been the subject of intensive cytogenetic study since 1933. They have also provided considerable information as to the chemistry of the chromosomes. Associated with the flight muscles of several groups of insects are some relatively large cytoplasmic bodies called "sarcosomes". Williams (16) has demonstrated that these structures, in dipteran muscle, are in fact giant mitochondria (1μ to 4μ diameter) which possess essentially the same biochemical properties and enzymatic activity as the mitochondria of mammalian liver cells (0.5μ to 2μ diameter in the guinea pig). The enzymatic properties of these large mitochondria have been intensively studied by Sacktor (11). More recently similar studies have been made of mammalian heart sarcosomes which have been found to have much in common with those in insect fibrillar muscle.

Although they exhibit a high degree of morphological and physiological specialization and of cellular differentiation, insects are characterized by certain primitive features. The segmental ganglia are to a considerable degree autonomous in their action; the blood has no respiratory function and as a result there is a limited development of the circulatory system; their metabolism is poikilo-

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thermic. Consequent upon these primitive features, insects can be subjected to mutilations and drastic treatments that would be fatal to most vertebrate organisms. For example, insects can survive dilution of the haemolymph with distilled water or extensive loss of blood volume far beyond the lethal limits for warm-blooded vertebrates. Some species can withstand prolonged anoxia, others can survive freezing of their tissues and most insects are relatively tolerant of ionizing radiations. This last attribute is perhaps of timely interest. Pertinent data from the entomological literature have been summarized by Howden (6). With respect to the lethal effects of gamma radiation the LD_{50}, in four weeks, for the adult female of *Drosophila melanogaster* is 60,000 roentgens. This may be compared with an LD_{50}, in 30 days, of 1270 roentgens for the white rat (13, p. 471). Thus in many cases insects can be subjected to experimental treatments well outside the limits of tolerance of higher organisms with an attendant extension of the range of experimental observations.

The comparative approach to physiological problems has frequently proved illuminating and within the class Insecta we have such a diversity of form and function that it is unnecessary to look further in order to obtain interesting comparative data. Due to the wide range of habitats in which insects are found it is usually possible to find one which is a suitable subject for study of the problem at hand. Probably the greatest hiatus in this regard is in marine forms where arthropods of other classes especially, the Crustacea, predominate. Insects range from aquatic forms to subterranean dwellers, from phytophagous through omnivorous to strictly carnivorous, from free-living solitary forms to obligate parasites. They exhibit a wide range of temperature tolerances which together with their poikilothermic metabolism has made possible the compilation of significant data on the temperature coefficients of metabolic processes.

Insect physiology as a specialized field of study has attained its greatest fruition during the last two decades in which time a large body of information has been gathered. Most studies in insect physiology have been undertaken to elucidate mechanisms intrinsic to the insect, however, the results of such studies frequently have had considerable significance for general physiology. Occasionally insects have been the organisms of choice in the investigation of a problem in general physiology. One of the most rewarding and significant contributions to cellular physiology arising out of a study in which insect material played a major role was Keilin's original investigation of the cytochrome pigments (7). This rediscovery of McMunn's "myohaematin" and "histohaematin" arose from Keilin's interest in the respiration of parasitic insects and helminths. It is significant that McMunn in his studies confined his attention to the tissues of birds and mammals. Due to the importance of haemoglobin in these organisms, his contemporaries argued that the compounds he obtained in his extracts were modified blood pigments or derivatives. This is a good example of the value of simple systems in contrast to the limitations of more complex systems in the solution of physiological problems. In insect thoracic musculature Keilin had a material which could be examined *in vivo* without the interference of haemoglobin or myoglobin both of which occlude direct spectroscopic observation of the functioning of the intracellular pigments in vertebrate tissues.

More recently further significant discoveries concerning the cytochrome pigments have resulted from Williams' studies on insect diapause and some interesting physiological relationships in cytochrome synthesis have been demonstrated (12, 17). In the diapausing pupa of *Platysamia cecropia*, cytochrome c is absent except in the intersegmental muscles of the abdomen. The re-

synthesis of this pigment during the post-diapause period is apparently mediated by the prothoracic gland hormone. Although maintenance during diapause is possible in the absence of cytochrome c, growth and differentiation only occur following the reconstitution of the complete cytochrome system. The diapausing cecropia pupa provides excellent material for the study of cytochrome synthesis and the biological significance of these pigments as related to growth and differentiation.

The role of the "B" vitamins as components of coenzyme systems in cellular oxidations is the key to their nutritional significance. The importance of these factors in insect nutrition is not surprising and has been repeatedly demonstrated. A significant contribution to our knowledge of the vitamins was the identification of carnitine as a member of the "B" complex essential for the development of larvae of the mealworm, *Tenebrio molitor* (2). In common with other "B" vitamins this component appears to be widely distributed (3). *Tenebrio* larvae have been used successfully in the bio-assay of materials for this vitamin. Carnitine's role is not fully known but it has been suggested that it is concerned in the transfer of two-carbon fragments. The discovery that carnitine may be an essential vitamin exemplifies the basic contributions that can be made by studies of insect nutrition.

Chemoreceptors achieve their greatest degree of development in the vertebrates and the insects. Although the morphological characteristics of insect chemoreceptors are quite different from those of the vertebrates there appears to be no essential difference in their physiological mechanism. From the standpoint of the experimenter the insect receptors have certain advantages. They are readily accessible and are free of mucous coatings. Unlike vertebrate receptors they are typically primary sense cells and their proximal processes run directly to the central nervous system uninterrupted by synapses. Minnich (8, 9) first demonstrated that contact chemoreceptors are present on the tarsi of adult Lepidoptera, flies, and bees and that stimulation of these receptors elicits extension of the proboscis. The presence of these receptors, remote from the feeding organs has many experimental advantages. These have been exploited by Dethier and his colleagues in many ingenious studies of chemoreception in the blowfly, *Phormia regina*. The results of these studies have contributed to the understanding of such basic problems of chemoreception as: the relationship between molecular structure and stimulating effectiveness and the mechanism of stimulation by sugars (1, 5).

Most of the data on chemoreception in insects have been based on behaviour responses. Early attempts at electro-physiological analysis were unrewarding. Recently however, successful electro-physiological studies have been made of single receptor organs on the labellum of the blowfly *Phormia regina* (4, 5). The organ contains two receptors, each innervated by its own fibre. One of the receptors is stimulated by sugars and the other by non-sugars. We have here a superb preparation for the study of an isolated chemoreceptor and the relation of its activity to the behaviour responses of the whole organism.

The few examples discussed here illustrate that insects can be fruitfully exploited in the investigation of physiological problems with findings which extend beyond those intrinsic to the understanding of the insect itself. These findings add to our confidence in the concept of the essential unity of life that has been well illustrated by modern biochemistry. The present status of insect physiology is, to a considerable extent, attributable to the successful application and refinement of the latest biochemical and biophysical techniques. We can

anticipate that, in the future, insects will be increasingly employed in physiological investigations to the enrichment of entomology as well as general and comparative physiology.

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